FINAL REPORT – PHASE II

Measurement and Modeling of Ecosystem Risk and Recovery for In Situ Treatment of Contaminated Sediments

SERDP Project ER-1552

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14. ABSTRACT
The main goal of this project is to improve the mechanistic understanding and ecological implications of the *in-situ* remediation technology that uses activated carbon (AC) to treat sediments contaminated by hydrophobic organic contaminants, and thereby advance the technology towards greater implementation. The results from long-term monitoring of field-scale AC amendment to sediment confirmed the progressive benefits achieved by AC over time, which was anticipated to occur according to the PCB mass transfer model. The PCB mass transfer model was further advanced considering various field conditions and engineering options and equipped with robust model parameters determined from independent tests. The PCB mass transfer model successfully reproduced the experimental results observed in 24-month column studies. The results advance engineering design and predictive performance of the *in-situ* AC treatment. Adverse effects of AC amendment were not observed on the *Neanthes* survival regardless of the sediment type, the AC dose (20% versus 5%) or the AC particle size. Without additional food supply, no significant differences on growth were observed. When feeding on fish food, there were some effects of AC on these deposit feeders, but absolute effects of AC amendments on growth and energy reserves were not significant.

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List of Acronyms

AC	Activated carbon
ANOVA	Analysis of variance
BC	Black carbon
DOM	Dissolved organic matter
DI	Deionized
GC	Gas chromatography
HOC	Hydrophobic organic compound
HP	Hunters Point
LOQ	Limit of quantification
MDL	Method detection limit
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PE	Polyethylene
POM	Polyoxymethylene
PRC	Performance reference compound
SPMD	Semipermeable membrane devices
TOC	Total organic carbon

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In-situ treatment
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I. Abstract

Project Overview

The overall goal of this project (ER-1552 Phase I, II, and III) is to develop methods for measurement and modeling of ecological risk and recovery for *in-situ* activated carbon (AC) amendment to treat hydrophobic organic contaminants (HOCs) in sediments. More specifically, the overall objectives are to (1) develop and validate an HOC mass transfer model to predict the long-term effectiveness of AC amendment, (2) develop a comprehensive strategy to assess ecological recovery after the AC amendment, (3) assess possible effects of AC amendment on benthic organisms, and (4) develop a cost-effective tool to monitor the contaminant concentration in sediment pore-water. In Phase I of the project, a passive sampling technique using polyethylene (PE) devices was developed as an inexpensive and easy method to determine pore-water HOC concentrations. A biodynamic modeling approach was used successfully to predict the contaminant burden at the base of the food web approach. A method was developed to estimate pore-water advection and dispersion using a theoretical heat transport model, which may improve the performance of the HOC mass transfer model. In Phase II, the HOC mass transfer model and the passive sampling techniques developed and enhanced in Phase I were used to improve the mechanistic understanding of the *in-situ* AC amendment, verify the benefit of the treatment to reduce the risk of HOCs in sediments, and develop a predictive tool for long-term effectiveness of the treatment. The possible adverse effects of AC amendment on local invertebrates, which had been investigated in Phase I, were comprehensively studied with emphasis on secondary effects. Phase III of the project will continue to i) study the changes in contaminant risk after accidental loss or retrieval of AC from treated sediment, ii) standardize the *in-situ* PE sampling technique, and iii) apply the AC treatment technique to treat pollutants in stormwater, which may recontaminate the remediation site.

Objectives of the Current Work

The main goal of the current work (Phase II) is to improve the mechanistic understanding and ecological implications of the *in-situ* remediation technology using AC to treat sediments contaminated by HOCs, and thereby advance the technology towards larger implementation. In order to achieve the goal, our project has two primary objectives: (1) Develop a mass transfer model to predict polychlorinated biphenyl (PCB) mass transfer under conditons relevant to field application of AC-amendment and assess the long-term performance and (2) Evaluate possible adverse effects of AC amendment on local invertebrates.

Technical Approach

Five-year post-treatment assessment was conducted at an inter-tidal mudflat adjacent to Hunters Point Shipyard, CA at which a pilot-scale AC amendment was applied in 2004. Various measures for the stability and effectiveness of the treatment including semi-permeable membrane device (SPMD) uptakes, PE sampler uptake, aqueous equilibrium concentrations, and total organic carbon (TOC) were analyzed. The results were compared to the results for the 1- and 7-month post-treatment assessment, which had been conducted in our previous ESTCP project (ER-0510). A PCB mass transfer model in AC-amended sediment with heterogeneous AC distribution and advective pore-water movement was developed and applied to interpret the temporal changes in the performance of field-amended AC to sediment at the site and predict the long-term effectiveness.

After the field assessments, the PCB mass transfer model was further enhanced to include a passive sampler phase to the model, to decrease the computation time, and to improve the user-friendliness. A series of laboratory experiments was conducted to obtain site-specific model input parameters for the sediment collected from the study site. Sediment column studies were conducted using the site sediment with variations in initial AC mixing regimes, AC distribution, AC particle sizes, hydraulic conditions, and AC-sediment contact times. The results of the column studies were used to validate the PCB mass transfer model using the site-specific parameters determined by the laboratory experiments.

Laboratory experiments were conducted to evaluate possible adverse effects of AC amendment on local invertebrates. Five sediment samples with various TOC, total nitrogen, and PCB and polycyclic aromatic hydrocarbon (PAH) concentrations were collected and used to test the non-toxic, secondary effects of AC amendment on survival, weight change, lipid content, and energetic biomarkers of the deposit feeder *Neanthes arenaceodentata*. Different AC dose, particle sizes, and food supply options were applied for comprehensive analysis.

Results

The results of the five-year post-treatment assessment at the field site confirmed the benefit of AC amendment. The PCB uptakes in passive samplers decreased up to 73% with a 3.7 dry wt% AC dose, confirming the temporal enhancement of the amendment benefit from a 19% reduction with a 4.4% dose observed within a month. The passive sampler uptake showed a strong local sorbent dose-response relationship. The model predictions using the PCB mass transfer model were fairly comparable to the measurements. Combining the monitoring and simulation results, the understanding on the long-term effectiveness of AC, the local AC dose-response relationship, the impact of fouling by natural organic matter, and the effect of advective pore-water movement could be improved. The modeling results suggested that the homogeneous incorporation of AC in the sediment will significantly accelerate the benefit of the treatment.

The results of the sediment column studies verified that a substantial AC benefit can be achieved when AC is homogeneously mixed into the sediment. After two years of stagnant contact in columns, the PCB uptake in PE samplers was reduced by 93-97% with 4 dry wt% AC dose. The AC benefit strongly depended on AC particle size and AC-sediment contact time. Increased AC benefit was achieved also by longer initial mixing time between AC and sediment, but re-mixing the sediment 5 days after the initial mixing did not show any enhancements. The effect of advective pore-water movement on AC benefit was not observed in the experiments. The PCB mass transfer model was validated with the column study results. The simulation results successfully reproduced the relative difference between different PCB congeners, and the effects of AC-sediment contact time, initial mixing regimes, AC distribution, and pore-water movement. In a quantitative manner, the model slightly underestimated the effectiveness of AC treatment for the column studies. This suggests that the PCB mass transfer model gives a relatively conservative prediction for the AC benefit.

No adverse effects of AC amendment were observed on the *N. arenaceodentata* survival regardless of the sediment type, the AC dose (20% versus 5%), or the AC particle size. Food supply was the major factor that affected the weight change, lipid content, and energetic

biomarkers analyzed in the experiments. Without additional food supply, exposure to untreated and AC-amended sediments resulted in similar reduction of weight and lipid content, with no difference between ingestible and non-ingestible AC. Overall, whether with or without AC, the organisms showed signs of starvation, as the organisms would most likely rely on organic surface deposits for their diet in the environments from which the sedimenst were collected. When additional food was supplied, the organisms grew significantly and maintained higher lipid and glycogen contents. However, when feeding on fish food, organisms grew less in AC amendments with slightly lower lipid and glycogen contents relative to organisms exposed to untreated sediment, presumably because AC sorbs the nitrogen from fish food. Despite some effects of AC on *N. arenaceodentata*, absolute effects of AC amendments on growth and energy reserves were not significant.

Benefits

Our PCB mass transfer model predicts the variable effectivenss of AC amendment with different AC application scenarios. The model certainly will be useful for site managers and DoD users who may be considering the *in-situ* AC amendment technology. The model provides site managers the ability to conduct screeing assessments for the selection and optimization of the engineering parameters for the treatment (e.g., AC particle size, mixing duration, mode of application, etc.).

Our study on possible adverse effects of AC amendment on local invertebrates concludes that the AC did not significantly impact the organism's survival, growth, energy reserves, or behavior for the deposit feeder tested in the presented work. Although future work is needed to better understand the effects on benthic communities for large-scale field deployments, our current results increase confidence for site managers or DoD users to consider this technology as a remedial option.

II. Objectives

Our recent ESTCP field project (ER-0510) showed the need for predictive models to assess the long-term performance of activated carbon (AC) amendment to sediment under quiescent field conditions and slow mass transfer encounted in the field as compared to well-mixed conditions in the laboratory. The field study demonstrated that sediments in a contaminated tidal mudflat could be amended with AC using commercial equipment, sequester contaminants and reduce exposures to pore-water and benthic organisms. We showed that AC in the field retained its capacity to continually sorb polychlorinated biphenyls (PCBs) months after deployment. However, less overall reductions in the field versus the laboratory calls for predictive models to assess long-term trends in PCB pore-water concentrations and availability under field conditions with slow mass transfer and heterogeneous AC distribution from brief mixing events. Additionaly, we need to further study possible adverse impacts on local benthic communities from AC sorbent itself, although our preliminary studies implied no undesirable effects by AC amendment on ecosystem health. Therfore, the main goal of this project is to improve the mechanistic understanding and ecological implication of the *in-situ* remediation technology using AC to treat sediments contaminated by hydrophobic organic contaminants (HOCs). This work will thereby advance the technology toward larger implementation. In order to achieve the goal, our project has two primary objectives within the scope of this project. Listed below are the two objectives with corresponding subtasks.

1. Develop a mass transfer model to predict PCB mass transfer under field AC-amendment conditions, and assess the long-term sequestration ability of field-aged AC (Task 6).

Subtask 6.2 PCB mass transfer model development and validation
Subtask 6.3 Field data collection
Subtask 6.4 Laboratory experiments

2. Evaluate possible adverse effects of activated carbon amendment on local invertebrates. Determine which marine invertebrate is most feasible as a biological indicator for risk assessment and monitoring the effects of PCB sequestration in marine sediments (Task 7).

Subtask 7.1 Choice of sorbent materials and test organisms
Subtask 7.2 Assess ingestible particle size of sorbents for test organisms
Subtask 7.3 Assessment of adverse effects of sorbent materials and invertebrates

III. Background

1. Mechanisms of *in-situ* stabilization and reduction of bioavailability.

The concept of activated carbon (AC) amendment for *in-situ* stabilization of hydrophobic organic contaminants (HOCs) builds on prior studies that describe the role of black carbon, e.g., soot, chars, and soot-like materials such as coal, to affect the transport, uptake, and biomagnification of HOCs in sediments (Ghosh, Gillette et al. 2000). Particle-scale analyses of sediment from the general study area at a field site in San Francisco Bay showed that the majority of HOCs were associated with black carbon-derived materials such as chars and were not as readily released to water (Ghosh, Gillette et al. 2000; Ghosh, Zimmerman et al. 2003). These black carbonaceous particles strongly affect the partitioning of HOCs due to their large surface area and adsorption affinity. Furthermore, several studies showed that strong sorption onto such particles is responsible for slower HOC release rates and reduction in HOC bioavailability (Kraaij, Ciarelli et al. 2001; Talley, Ghosh et al. 2002).

These observations led to the idea of using strong carbonaceous sorbent to shift contaminant sorption from a readily-available state to a strongly-sorbed state. This would significantly enhance a process that was occurring naturally, albeit slowly. Zimmerman et al. tested coke and activated carbon as such sorbents, and found that AC showed significantly greater performance to reduce polychlorinated biphenyl (PCB) availability to the aqueous phase than coke (Zimmerman, Ghosh et al. 2004). The much greater specific surface area and the pore structure of AC appeared to account for the greater effectiveness. Strong sorption to AC would reduce the absorption (i.e., the bio-uptake) of HOCs to sediment biota. This was confirmed by McLeod et al. who showed significantly lower absorption efficiency of radio-labeled benzo(a)pyrene and a PCB congener by a marine clam from AC compared to other carbonaceous particle types (McLeod, Van Den Heuvel-Greve et al. 2004). As shown in Figure 1, the absorption efficiency is the highest for wood and diatoms and the lowest for AC.

A conceptual schematic of the *in-situ* stabilization of HOCs by AC amendment is shown in Figure 2. Incorporation of AC into sediment particle promotes repartitioning of contaminants from the more readily-available sorbed fraction onto AC particles. In consequence, the strongly sorbed contaminants become much less available to biota either via contact with water or by particle ingestion.

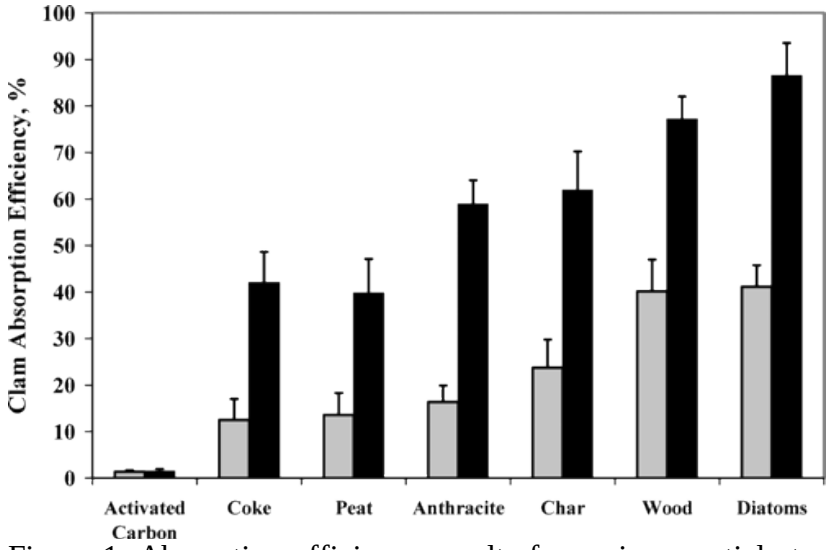


Figure 1. Absorption efficiency results for various particle types for the marine clam *Macoma balthica*. Light columns represent the polycyclic aromatic hydrocarbon benzo(a)pyrene; dark columns represent PCB-52. Error bars show 95% confidence intervals. For the particles tested, absorption efficiency for either compound is the lowest for activated carbon and the greatest for wood and diatoms (McLeod, Van Den Heuvel-Greve et al. 2004).

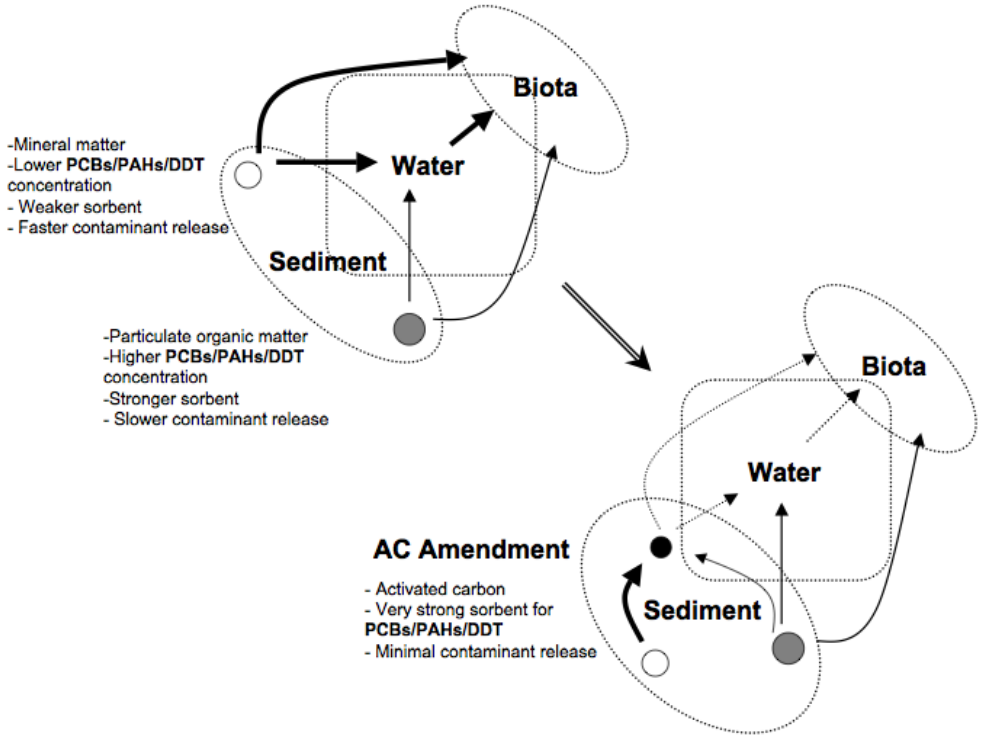


Figure 2. Schematic of the mechanisms involved with application of AC amendment to sediment in reducing exposure and environmental risk by lowering HOC release to water and bio-uptake by benthic biota, either by filter feeding or deposit feeding.

2. Previous Studies of AC Amendment for *In-situ* Treatment.

Various studies showed that incorporating AC into HOC-contaminated sediment would re-partition the HOCs, making them less available to pore-water and biota (Zimmerman, Ghosh et al. 2004; Millward, Bridges et al. 2005; Zimmerman, Werner et al. 2005; Cho, Smithenry et al. 2007; Tomaszewski, Werner et al. 2007; Cho, Ghosh et al. 2009; Hale, Tomaszewski et al. 2009). For instance, introducing 3.4 dry wt% of AC into well-mixed sediment-water slurries in the laboratory showed about 90% reductions of PCBs, PAHs and DDT in water and benthic organisms (Zimmerman, Ghosh et al. 2004; Millward, Bridges et al. 2005; Zimmerman, Werner et al. 2005; McLeod, Luoma et al. 2007; McLeod, van den Heuvel-Greve et al. 2007; Sun and Ghosh 2007; Tomaszewski, Werner et al. 2007). Mixing about 2% AC into the top 30-cm sediment layer at a mud flat in San Francisco Bay gave 50-70% reduction in PCBs in pore-water, passive samplers, and benthic test organisms (Cho, Smithenry et al. 2007; Cho, Ghosh et al. 2009).

3. Mass Transfer in Intertidal Sediment.

Models are needed to explain the laboratory results with well-mixed systems, field results with minimally mixed systems, and furthermore the differences between them. From both engineering management and regulatory decision-making perspectives, models are the only means for making longer-term predictions about performance and estimating the time required to achieve an eventual quasi-equilibrium state, as illustrated in Figure 3. Such models must consider: 1. diffusive mass transfer under quiescent conditions, 2. advective pore-water movement in intertidal and sub-tidal regions, 3. effects of dissolved organic matter on reducing the mass transfer and/or sorption capacity of the AC, and 4. the distribution of AC particles within the sediment, e.g., uniformly distributed as in a well-mixed laboratory test or heterogeneously distributed as in a field test, or possibly layered.

Mass transfer under field conditions may occur quiescently, where diffusion processes limit HOC mass transfer. To explain HOC mass transfer in a stagnant system, Werner, Ghosh & Luthy developed a mass transfer model of an unmixed system with sorption-retarded molecular diffusion (Werner, Ghosh et al. 2006). An example of this model (Hale and Werner 2010) is shown in Figure 3, which shows that HOC mass transfer to AC in a quiescent system is greatly retarded and the full effect of AC on reducing HOC pore-water concentrations could be delayed for several years to approach near equilibrium.

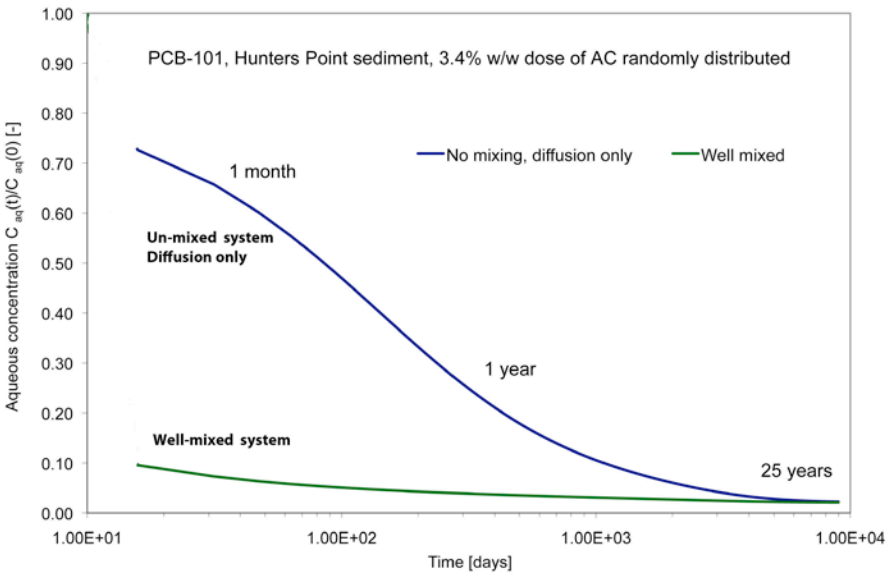


Figure 3. Model simulation of reductions in PCB pore-water concentrations for a continuously well-mixed system and for a system having randomly distributed AC particles and no advective pore-water movement by tides or wave action. After an initial decline, systems with no pore-water movement require several years to approach near equilibrium. The approach towards equilibrium depends on the extent of pore-water movement, e.g., by tides or wave action, and the distribution and size of the AC.

4. Effects of Dissolved Organic Matter on AC Performance.

Although AC has a high sorption capacity for HOCs, the performance of AC in sediment is likely to be affected by dissolved organic matter (DOM) that may compete with or slow the uptake of HOCs. Hale et al. evaluated these effects for DDT (Hale, Tomaszewski et al. 2009). Employing passive samplers allowed the measurement of AC-clean water partitioning coefficients at environmentally relevant, free aqueous concentrations. A mass transfer model revealed that the sorption coefficient, K_{AC}, determined for AC-clean water was not applicable to AC mixed with sediment and overestimated the AC sorption capacity. This was likely due to DOM in sediment pore-water diminishing the AC uptake rate, akin to fouling. However, increasing the sediment-AC contact time decreased the effect of DOM and we infer the presence of DOM does not alter the actual AC sorption capacity over longer periods, rather the effect of the DOM is kinetic not thermodynamic. Thus, the benefits of AC amendment will likely be manifest in time (Tomaszewski, Werner et al. 2007; Tomaszewski, McLeod et al. 2008), but to completely understand the process of AC fouling, long-term sorption experiments are needed, and these effects need to be incorporated in a general predictive model.

5. Effects of AC Sorbent on Benthic Invertebrates.

A large body of literature shows significant reduction of HOC aqueous concentrations and benthic organism bioaccumulation for AC amendments of approximately 2% to 4% by dry weight to the sediment (Zimmerman, Ghosh et al. 2004; Millward, Bridges et al. 2005; Cornelissen, Breedveld et al. 2006; McLeod, Van den Heuvel-Greve et al. 2007; Tomaszewski, Werner et al. 2007; Brandli, Hartnik et al. 2008; Sun and Ghosh 2008; Cho, Ghosh et al. 2009;

Janssen, Croteau et al. 2010). Having established that AC amendments can effectively reduce bioaccumulation, the attention of bioassays has lately focused on possible secondary effects of AC on the health of benthic organisms. A recent study demonstrated that the deposit feeding oligochaete *Lumbriculus variegates* was highly sensitive to AC addition to sediment even at a dose of only 1%, which caused up to 92% reduction of feeding (Jonker, Suijkerbuijk et al. 2009). Some studies observed reduced lipid contents after exposure to AC amendments (Jonker, Hoenderboom et al. 2004; Millward, Bridges et al. 2005; Jonker, Suijkerbuijk et al. 2009; Janssen, Oen et al. 2011). Other studies report no influence of AC on organism growth or lipid contents, and some observed an increase of survival when exposure to pollutants was reduced by AC addition (Tomaszewski and Luthy 2008; Janssen, Croteau et al. 2010; Kupryianchyk, Reichman et al. 2011). Most of the previous studies were designed to assess contaminant bioaccumulation rather than an organism's health during exposure. While AC amendment reduces the availability of HOCs to benthic organisms, other organic molecules, including dissolved organic carbon, and nutrients may become less available as well. Reduced availability may result from sorption within the sediment or competition within the gastrointestinal tract of the organism when AC is ingested with the diet (Figure 4).

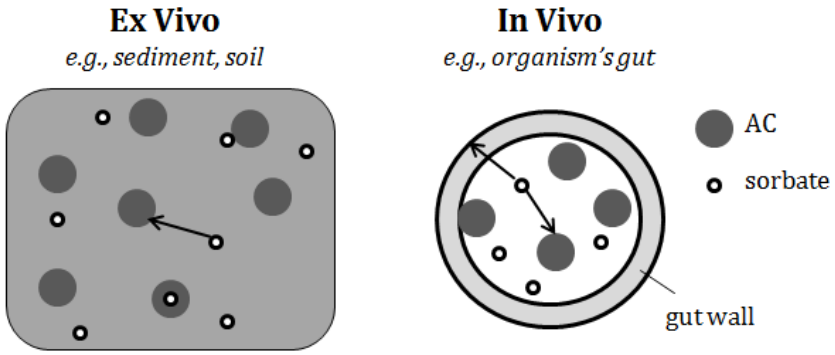


Figure 4. Schematic of sorption mechanisms of activated carbon: Ex Vivo: repartitioning within the sediment; In Vivo: sorption to ingested activated carbon particles in competition with assimilation within the gastrointestinal tract.

IV. Materials and Methods

1. Mass transfer modeling and long-term effectiveness (Task 6)

1.1. Long-term field monitoring and initial model development of the mass transfer of polychlorinated biphenyls in sediment following pilot-scale *in-situ* amendment with activated carbon (Tasks 6.2 and 6.3)

1.1.1. Site description.

Test sites are located at an inter-tidal mudflat adjacent to Hunters Point Shipyard, CA, USA (Figure 5A and B), wherein the sediment is impacted by polychlorinated biphenyls (PCBs) with a concentration range of 1-10 mg kg^{-1} (Battelle, Entrix Inc. et al. 2004). Two field-scale trials of activated carbon (AC) amendment by mechanical mixing devices (Cho, Smithenry et al. 2007; Cho, Ghosh et al. 2009) have been conducted. In August 2004, about 3 dry wt% of AC (Calgon TOG-NDS, 50 × 200) was incorporated into the test plot A that was located 15 m away from the shoreline (Figure 5C). The control plot (Plot B) remained undisturbed. The second AC application was carried out in January 2006 on the test plot D, which is separated by 1.5 m from Plot B and positioned closer to the shoreline. The control plot for Plot D (Plot C) was mechanically mixed using the mixing device without AC sorbent to homogenize the upper 30-cm sediment layer, which had a more stratified structure than plots A and B. Detailed descriptions about the AC deployment and mixing can be found elsewhere (Cho, Smithenry et al. 2007; Cho, Ghosh et al. 2009).

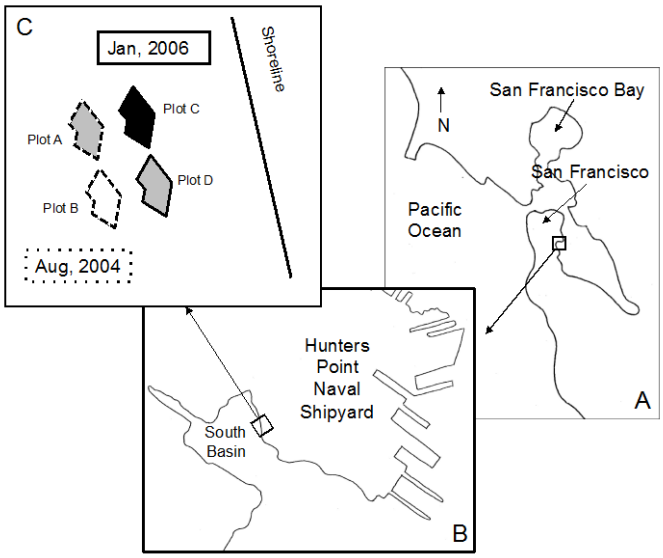


Figure 5. Schematic of (A) San Francisco Bay; (B) Hunters Point Naval Shipyard and South Basin; and (C) four test plots (A-B and C-D). The two plots indicated by shading (Plots A and D) were treated by mixing the sediment with AC to a nominal 30-cm depth. Plot B served as an unmixed control plot for Plot A, and Plot C served as a mixed control plot for Plot D.

1.1.2. Assessment design and timeline.

For Plots A and B, post-treatment assessments were conducted in September 2004, March 2005, and September 2009, which corresponds to 1 month, 7 months, and 5 years post AC amendment, respectively (Table 1). Details about the 1-month and 7-month post-treatment monitoring are reported by Cho et al. (2007). To investigate the long-term benefit and stability of AC amendment, an additional field-assessment was conducted in September 2009, about 5 years after the AC deployment on Plot A (Table 1). The 5-year post-treatment assessment comprised the use of 28-day semi-permeable membrane device (SPMD) uptakes and total organic carbon (TOC) measurements of sediment in the AC-treated plot A and the control plot B. Sampling activities took place at the left bottom quarter of each fan-shaped test plot to minimize possible impacts from previous sampling events. Three SPMDs were deployed in each test plot within the 0-10 cm sediment layer using a stainless steel tubing frame. Three 15-cm-long sediment cores were collected adjacent to the SPMD sampling locations to assess TOC. Each sediment core was divided into three sections of 5 cm length (2 inches), which were homogenized and sampled for TOC analysis. The sections were combined to give a composite sample for the analyses of aqueous and sediment PCB concentrations. Additionally, a local AC-dose treatment response was studied *in-situ* using polyethylene samplers (PEs) deployed at variable depths. Three PE samplers (20 cm wide and 2.5 cm long) were installed with a stainless steel tubing frame, and two frames were deployed in each plot to place PEs within 5-10 cm, 10-15 cm, and 15-20 cm below the sediment surface. After 28 days of contact, a sediment core was taken next to the sampler frame to assess the local TOC as close as possible to the PE samplers. For plots C and D, post-treatment assessments were conducted in July 2006 and July 2007, which corresponded to 6 months and 18 months after the AC amendment on Plot D, respectively (Table 1). For this study, the following additional post-treatment assessments were conducted in plots C and D in September 2009 (3.5 years after AC amendment): TOC analysis and measurement of *ex-situ* aqueous and sediment PCB concentrations (Table 1).

Table 1. Timeline of AC deployment and post-treatment assessments for test plots. The first column refers the field activities, the second column provides the date of the sampling activities, and the last column describes the assessments for each sampling event.

Plots A and B		
AC deployment (Plot A)	August 2004	
1 month post-monitoring	September 2004	SPMD[1], TOC[2]
7 month post-monitoring	March 2005	SPMD, TOC
5 year post-monitoring	September 2009	SPMD, TOC, AQ[3], PE[4]
Plots C and D		
AC deployment (Plot D)	January 2006	
6 month post-monitoring	July 2006	TOC, AQ
18 month post-monitoring	July 2007	TOC, AQ
3.5 year post-monitoring	September 2009	TOC, AQ

[1.] Semipermeable-membrane device (SPMDs) 28-day uptake experiment
[2.] Total organic carbon content (TOC) for 5-cm sediment sections
[3.] Aqueous PCB concentration (AQ) by 14-day mixing
[4.] Polyethylene devices (PE) 28-day uptake experiment

1.1.3. Core sampling and TOC analysis.

Each 5-cm cross section of sediment cores was homogenized by stirring manually with a stainless-steel spatula, and then approximately 1 g of sediment was subsampled for elemental analysis. These subsamples were dried and ground using an agate mortar and pestle. Approximately 4 mg of each sub- sample was weighed into a silver boat. Weighed samples were then acidified in situ with 6% sulfurous acid to remove carbonate phases (Verardo et al., 1990). Each sediment sample was analyzed for total organic carbon (TOC) using a Carlo Erba NA-1500 elemental analyzer. Carbon analysis errors were <0.5% based on an acet- anilide standard (71.1 wt.% C).

1.1.4. Millimeter-scale TOC analysis.

To assess the millimeter-scale heterogeneity of the AC distribution in sediment, a 5-cm-long sediment core was taken from the 5-10 cm deep sediment layer of the AC-treated plot D. From the sediment core, thirty samples were randomly collected with each containing about 100 mg of dry sediment using a micro-spatula, which were analyzed for TOC. The background TOC was assessed by sampling from a 5-cm-long sediment core from the same depth at reference plot C. The AC dose for each sample was calculated using sample TOC (dry wt. %), the background TOC (TOC_0), and that for AC (TOC = 86.1%) (Cho, Ghosh et al. 2009) as

$$AC\ dose(\%) = \frac{(TOC - TOC_0)}{(86.1 - TOC)} \quad (1)$$

1.1.5. PCB measurements.

Analyses of sediment PCB concentrations, aqueous concentrations, and *in-situ* SPMD/PE uptakes followed the methods described by Cho et al. (Cho, Ghosh et al. 2009). Briefly, sediment PCB concentrations were determined by sediment extraction with sonication in a 50/50 (v/v) hexane/acetone mixture, following a procedure based on EPA Method 3550A. Aqueous PCB concentrations were determined *ex-situ* after contacting water and sediment for 14 days in rotated bottles. Colloids were removed using flocculation and centrifugation and PCBs were extracted from the aqueous phase three times with hexane (Ghosh, Gillette et al. 2000). PCB uptakes into passive samplers (SPMD or PE) were determined by solvent extraction using hexane. Briefly, after retrieval, the SPMDs were cleaned by rinsing with deionized water, swirling for 30 s in 1 M hydrochloric acid, rinsing with the series of deionized water, acetone, and isopropyl alcohol, and air-drying for approximately 30 s. The SPMDs were then submerged in approximately 125 mL of hexane and dialyzed at room temperature for 24 h. The dialysate was removed, and dialysis with fresh hexane was repeated for 8 h. Dialysates were combined with hexane rinse, the total volume was recorded, and aliquots were taken for cleanup. For PE samplers, the PEs were cleaned, submerged in approximately 40 mL of hexan, andextracted for 24 h.

1.1.6. PCB Analysis.

Sulfur interferences were removed following EPA SW846 Method 3660A. Organic interferences were removed following EPA Method 3630C. PCB congener specific analysis was performed using a modified EPA Method 8082. An Agilent gas chromatograph (model 6890) with a fused

silica capillary column (HP-5, 60 m x 0.25 mm ID) and a micro electron capture detector were used for analysis. A 5-level PCB calibration table was prepared using a known PCB mixture from the EPA's National Health and Environmental Effects Research Laboratory, Grosse Ile, MI (Mulline, 1994). Two internal standards were used: PCB-30 (2,4,6-trichlorobiphenyl) and PCB-204 (2,2',3,4,4',5,6,6'-octachloro biphenyl).

1.1.7. PCB Congener Analysis.

A total of eight PCB congeners were examined in this study: PCBs 101, 151, 153, 149+129, 163+136, and 180. These congeners are the major PCBs that exist in the site sediment, pore-water, and passive sampler uptake, and comprise about 15-40 % of total PCBs. By focusing on these major congeners, instrument signals below the method detection level (MDL) were minimized and a reliable comparison in terms of total PCBs between controls and the AC-treated plots was obtained. All signals were detectible by GC-ECD. For sediment and passive sampler samples, all signals were above MDLs. For pore-water samples from AC-treated sediment, there were a few signals below MDLs, which were adjusted to MDLs to obtain a conservative estimate of the benefit of the AC amendment. MDL values and the method of determination are shown in Table 2. Analytical methods for PCB congeners were consistent throughout all post-assessments, and described in detail by Cho et al. (2007 and 2009).

Table 2. Method detection limits for PCB congeners

Congener	Aqueous concentration (ng/L)	Passive sampler uptakes (µg/kg SPMD or PE)	Sediment concentration (mg/kg)
PCB 101	0.08	0.36	0.06
PCB 151	0.08	0.20	0.03
PCB 153	0.12	0.20	0.03
PCB 149+129	0.08	0.16	0.03
PCB 163+136	0.04	0.20	0.03
PCB 180	0.04	0.14	0.02

1.1.8. Model Design.

The model used in this study builds on previous efforts to simulate the mass transfer of pollutants in sediment after AC amendment (Werner, Ghosh et al. 2006; Hale and Werner 2010). Overall, this model embraces the concept of intra-particle diffusion of contaminants by different particle types, distinguishing between two different sediment particles types (or sorption domains): one with slow intra-particle diffusion and slow desorption of contaminants ($rate_{slow}$), and the other with relatively faster intra-particle diffusion and desorption ($rate_{fast}$) (Figure 6). The third particle domain in the model is AC, which has the slowest diffusion/sorption kinetics because of its very strong sorption ability for PCBs (Figure 6). The model can simulate a series of different mixing regimes either for a well-mixed system or for a quiescent system. In this study, the model comprised up to three stages of different mixing regimes or steps for AC-sediment contact. These mixing regimes or stages are described below.

First, a well-mixed batch system model developed by Werner et al. (2006) was used to simulate the initial mechanical mixing period in the field during sorbent placement (~ 30 min). As the mechanical mixing device could only mix a portion of the whole area at a time, the simulated local mixing time was reduced to 1 min considering the ratio of the dimensions of the mixing devices (0.5m×2.5m) and size of the test plots (34.4 m^2). After 1 min mixing, the model output of intra-particle concentration profiles and aqueous concentrations from the well-mixed system were invoked as initial conditions for the next simulation.

Secondly, AC-sediment contact after the initial mixing period was simulated using the unmixed sediment model described by Hale and Werner (2010). Briefly, the unmixed sediment model system was formulated by stacking small sub-volumes (cubes) vertically and horizontally, some sub-volumes with AC particles and some without, where the kinetics of the local sorption process of the PCB within each cube was simulated based on intra-particle diffusion kinetics (Figure 6). The assumptions underpinning this modeling approach were conservative to obtain a prediction of the minimum treatment effectiveness as discussed by Hale and Werner (2010). Briefly, the model assumed no flux boundary conditions at all external boundaries of the sediment model system and in the center of the sediment and AC particles. Also, an instantaneous local PCB sorption equilibrium was assumed between the outer surface of the particles and the local aqueous phase. This model also allows us to simulate the uptake of PCBs by passive PE samplers placed in the sediment after a certain AC-sediment contact time. The model was also used to simulate PCB uptake by SPMDs by substituting the PE-water partitioning coefficient with the SPMD-water partitioning coefficient estimated according to Booij et al. (2002).

Lastly, the additional mixing period during the 14-day *ex-situ* aqueous equilibrium tests using field sediment cores was simulated using the well-mixed batch model and the information from the second phase (as given by the unmixed sediment model). The intra-particle concentration profiles and aqueous concentrations were averaged to provide the initial condition for this simulation.

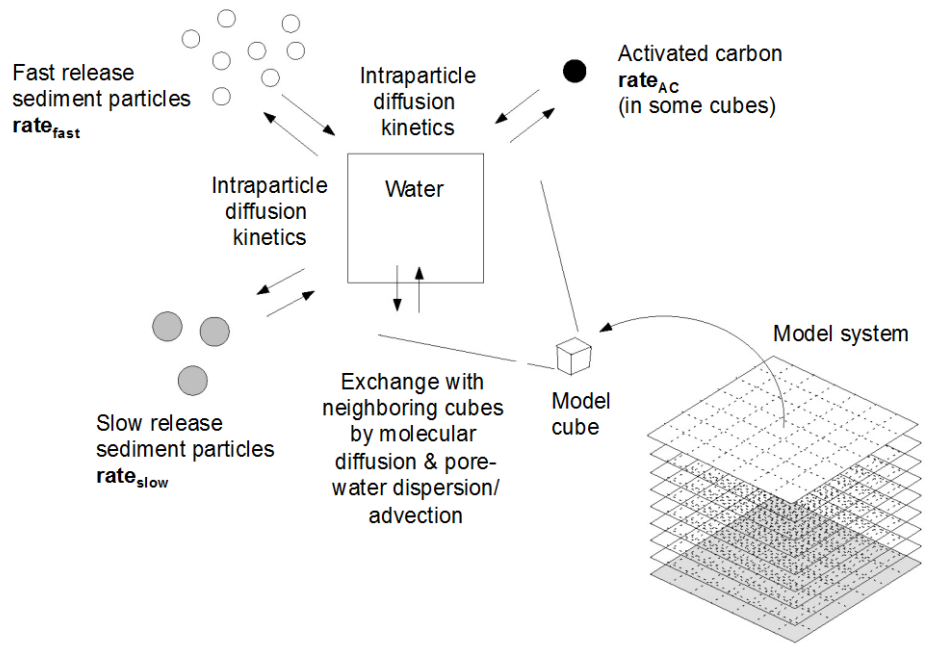


Figure 6. The conceptual framework for a model of HOC transport for a minimally mixed sediment system. Movement of contaminants between neighboring cubes can occur by molecular diffusion in pore-water, pore-water dispersion, or advective flow. There are three model system compartments: domains of fast release sediment particles, domains of slow release sediment particles, and AC, respectively. The parameters $rate_{fast}$, $rate_{slow}$, and $rate_{AC}$ are the PCB congener release rates (for slow and fast release sediment particles, s^{-1}) or uptake rate (for AC, s^{-1}).

1.1.9. Model formulation.

In this study, the unmixed model described by Hale and Werner (2010) was modified to allow for the simulation of possible advective pore-water movement in settled sediment. Recently, Cho et al. (2010) estimated from temperature profiles and heat transfer modeling the average magnitude of advective pore-water velocity in the vertical direction at the Hunters Point mudflat test site as 5 cm d^{-1} with a plausible range of 0 to 14 cm d^{-1}. The basic mass balance equation of the numerical model was modified to account for advective pore-water flow as described in the following equation: .

$$\frac{dS_{aq}(x,y,z,t)}{dt} = D_{disp}\left[\frac{\partial^2 S_{aq}(x,y,z,t)}{\partial x^2}+\frac{\partial^2 S_{aq}(x,y,z,t)}{\partial y^2}+\frac{\partial^2 S_{aq}(x,y,z,t)}{\partial z^2}\right]$$
$$-\frac{V_{sed}(x,y,z)}{V_{aq}}\cdot\frac{d}{dt}\left[3\int_0^1 q^2 S_{sed\_fast}(x,y,z,q,t)dq+3\int_0^1 q^2 S_{sed\_slow}(x,y,z,q,t)dq\right]$$
$$-\frac{V_{AC}(x,y,z)}{V_{aq}}\cdot\frac{d}{dt}\left[3\int_0^1 q^2 S_{AC}(x,y,z,q,t)dq\right]-u_z\frac{\partial S_{aq}(x,y,z,t)}{\partial z} \qquad (2)$$

where V_j (cm^3) and S_j ($g\ cm^{-3}$) denote the total volume of each phase component in the cube and the volumetric pollutant concentration in that phase respectively, and q (-) the radial distance from the particle center divided by the particle radius. S_{sed_fast} ($g\ cm^{-3}$) is the amount of contaminant associated with $rate_{fast}$ per total volume of sediment and S_{sed_slow} ($g\ cm^{-3}$) is the amount of contaminant associated with $rate_{slow}$ per total volume of sediment. D_{disp} ($cm^2\ s^{-1}$) denotes the dispersion coefficient, and u_z ($cm\ d^{-1}$) the pore-water velocity in z direction. The implementation of the intraparticle diffusion part of this model is based on the explicit numerical scheme described by Wu and Gschwend (1988).

Furthermore, we developed a modeling procedure to investigate the effect of the spatial AC distribution by assigning AC particles to different sub-volumes of the sediment matrix in various ways. In field applications, the AC distribution is expected to vary depending on mechanical mixing techniques and operational modes. First, two modes of AC distribution were considered by varying the characteristic length of diffusion: 1) homogenously distributed AC with approximately 0.2 mm average pore-water diffusion distance and 2) poorly distributed AC with approximately 1 mm pore-water diffusion distance. To construct a homogeneously distributed AC-sediment system, AC particles were randomly assigned to sub-volumes of the sediment, until all AC particles had been allocated. This routine results in a random, but relatively homogeneous AC distribution. In the other case, a poorly distributed AC-sediment system was simulated by placing AC particles in a thin layer on one boundary (x-z plane) of the model stacked-cube system. We also estimated a plausible AC distribution in the test plots based on experimental data, using information from two types of AC dose measurements: 5-cm averaged values for 30-cm sediment cores and mm-scale analysis for a 5-cm core (Figure 7). In this case, the model system was divided into 5-cm sections and the AC dosage for each section was determined from 5-cm averaged data for a selected sediment core (Figure 7A). Each section was further divided into subsections of 2 mm thickness in the vertical direction, for which the average AC doses were assigned by random selection of a weighing factor for the 5-cm averaged data. Thirty such weighing factors were determined as the ratio of the actual AC dose, relative to the average AC dose for the mm-scale micro AC-distribution measurements (Figure 7B). Finally, within each 5-cm subsection, AC particles were randomly assigned to have the AC dose determined as described above (Figure 7C). To obtain acceptable computation times, 30 cm long cores were simulated with a very narrow base of 1 mm^2 plan surface area using a uniform 0.2 mm grid resolution of the spatial domain. Advective pore-water movement was simulated in the vertical direction.

In this study, PCBs 101, 153, and 180 were simulated with various conditions and compared with field data. The model parameters for these compounds are shown in Table 3 and model conditions are summarized in Table 4, Table 5, and Table 6.

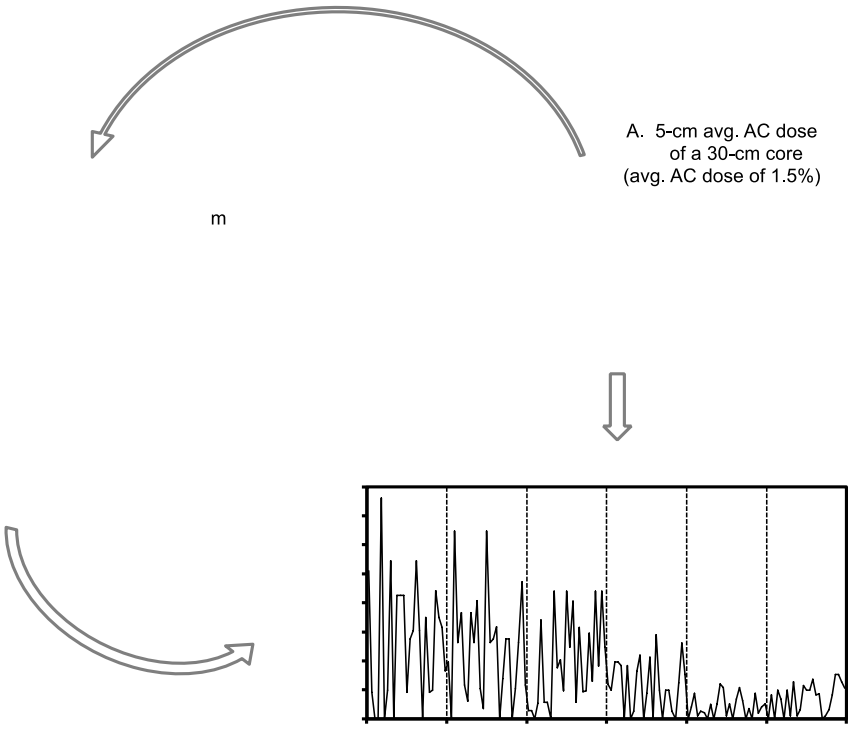


Figure 7. Construction of a plausible AC distribution in the model system using mm-scale TOC values and 5-cm average TOC measurements (an example of a sediment core with a 1.5 dry wt% AC dose).

Table 3. Modeling parameters common for three PCB congeners

PARAMETER	PARAMETER ANNOTATION	VALUE	SOURCE
AC particle radius	r_{ac} (cm)	**0.0075**	(Werner, Ghosh et al. 2006)
AC solid-phase density	d_{ac} (gcm^{-3})	**1.96**	(Werner, Ghosh et al. 2006)
AC porosity	p_{ac} (-)	**0.55**	(Werner, Ghosh et al. 2006)
AC dose	dose (gg^{-1})	**Variable**	Measured
sediment pore-water tortuosity	τ (-)	**0.57**	(Cho, Werner et al. 2010)
bulk dry sediment density	d_s (gcm^{-3})	**2.3**	(Maeba 2009)
pore-water velocity	u (cmd^{-1})	**5**	(Cho, Werner et al. 2010)

Table 4. Parameters for PCB 101

Parameter	Parameter Annotation	Value	Source
AC-water partitioning coefficient	K_{AC} (cm^3g^{-1})	$10^{8.0}$	(Werner, Ghosh et al. 2006)
contaminant uptake rate by AC	$rate_{AC}$ (s^{-1})	1.8×10^{-14}	Estimation; computed with K_{AC}, D_{aq}, p_{ac}, d_{ac} (Werner, Ghosh et al. 2006)
fast release rate from sediment	$rate_{fast}$ (s^{-1})	2.2×10^{-7}	(Zimmerman 2004)
mass fraction of PCBs initially associated with $rate_{fast}$	f_{fast} (-)	0.34	(Zimmerman 2004)
slow release rate from sediment	$rate_{slow}$ (s^{-1})	9.7×10^{-10}	(Zimmerman 2004)
water-phase diffusion coefficient	D_{aq} (cm^2s^{-1})	4.9×10^{-6}	(Schwarzenbach, Gschwend et al. 2003)
bulk sediment-water partitioning coefficient	K_d (cm^3g^{-1})	7.0×10^{4}	(Zimmerman 2004)

Table 5. Parameters for PCB 153

Parameter	Parameter Annotation	Value	Source
AC-water partitioning coefficient	K_{AC} (cm^3g^{-1})	$10^{8.6}$	(Zimmerman 2004)
contaminant uptake rate by AC	$rate_{AC}$ (s^{-1})	4.1×10^{-15}	Estimation; computed with K_{AC}, D_{aq}, p_{ac}, d_{ac} (Werner, Ghosh et al. 2006)
fast release rate from sediment	$rate_{fast}$ (s^{-1})	1.9×10^{-7}	(Zimmerman 2004)
mass fraction of PCBs initially associated with $rate_{fast}$	f_{fast} (-)	0.34	(Zimmerman 2004)
slow release rate from sediment	$rate_{slow}$ (s^{-1})	3.2×10^{-10}	(Zimmerman 2004)
water-phase diffusion coefficient	D_{aq} (cm^2s^{-1})	4.8×10^{-6}	(Schwarzenbach, Gschwend et al. 2003)
bulk sediment-water partitioning coefficient	K_d (cm^3g^{-1})	5.9×10^{5}	(Zimmerman 2004)

Table 6. Parameters for PCB 180

Parameter	Parameter Annotation	Value	Source
AC-water partitioning coefficient	K_{AC} (cm^3g^{-1})	$10^{8.6}$	(Zimmerman 2004)
contaminant uptake rate by AC	$rate_{AC}$ (s^{-1})	3.9×10^{-15}	Estimation; computed with K_{AC}, D_{aq}, p_{ac}, d_{ac} (Werner, Ghosh et al. 2006)
fast release rate from sediment	$rate_{fast}$ (s^{-1})	1.1×10^{-7}	(Zimmerman 2004)
mass fraction of PCBs initially associated with $rate_{fast}$	f_{fast} (-)	0.31	(Zimmerman 2004)
slow release rate from sediment	$rate_{slow}$ (s^{-1})	1.1×10^{-10}	(Zimmerman 2004)
water-phase diffusion coefficient	D_{aq} (cm^2s^{-1})	4.6×10^{-6}	(Schwarzenbach, Gschwend et al. 2003)
bulk sediment-water partitioning coefficient	K_d (cm^3g^{-1})	1.2×10^{6}	(Zimmerman 2004)

1.2. PCB mass transfer model enhancement, expansion, calibration, and validation (Tasks 6.3 and 6.4).

Based on the initial model developed for field-AC-amended sediment (Task 6.3), a mass transfer model was constructed for sediment column studies. The mass transfer model was further modified for computational enhancement, inclusion of passive samplers, and user-friendly I/O. The sediment column studies were designed to mimic field AC amendment events considering various field and engineering conditions such as AC-sediment mixing mode, advective flow, AC particle size, and AC distribution. The results from the column study were used for the model validation. To determine input parameters for the PCB mass transfer model, various laboratory experiments were conducted (Table 7).

Table 7. Laboratory experiments for model parameter determination.

Experiment	Parameter
PE preloading test, AC isotherm test	K_{AC_clean} (cm^3g^{-1}), $D_{AC,eff}$ (cms^{-1})
Desorption test	$rate_{fast}$ (s^{-1}), $rate_{slow}$ (s^{-1}), f_{fast} (-)
PE preloading test, PE isotherm test	K_{PE} (cm^3g^{-1})
AC fouling test	$K_{AC\ apparent}/K_{AC\ clean}$
14-day aqueous equilibrium test	C_{aq} (gcm^{-3}), K_d (cm^3g^{-1})

1.2.1. Sediment.

Sediment for the column experiments and other laboratory tests was collected from the mudflat in Hunters Point Shipyard in May 2010. The sampling location was selected close to the plot B (unmixed control) from our previous field studies (Cho, Smithenry et al. 2007) for consistency, but separated about one meter away from the border of the plot B to prevent possible influence from the previous sampling activities. Sediment samples were collected from the top-15-centimeter layer to consider a biologically active zone. The collected sediment was further sieved and homogenized in the lab on a 2-mm sieve to remove large gravel, shell material, and debris. Sediment was archived at 4ºC until further analysis.

1.2.2. Sediment column study.

Laboratory column experiments were conducted to simulate field conditions for *in-situ* stabilization by AC amendment, monitor longer-term changes in pore-water concentrations under diffusion-limited conditions, and compare various AC amendment conditions of AC particle size, mixing regime, and AC distribution. The experiment layout is depicted in Figure 8. Five AC mixing/dosing scenarios are considered using AC with a size range of 75-150 μm: 2 min mixing, 30 min mixing, 2 times of 2 min mixing with 5 days apart, layered AC distribution, and a control without AC. Additionally, the columns with the finest size AC (<45 μm) and 2 min mixing were constructed to see the effect of AC particle size on kinetics of mass transfer of PCBs. Two hydraulic conditions were considered for each mixing scenario: no flow and 5 cm/d advective flow (10 cm/d face velocity with a porosity of 0.5). The AC dosing was 4 dry wt% for all AC-amended conditions and duplicate columns were run for each condition.

About 550 g of wet sediment was placed into a 1-L wide mouth jar, 1 g/L of sodium azide (as pore-water concentration) was added to prevent microbial activity, and about 0.6 g of PE sampler was added as 50-60 thin trips to monitor pore-water PCB concentration. The sediment was mixed with PE samplers and AC using a double-wheel mixer head (5 inch in width) attached to an electrical hand drill at approximately 250 rpm. Including the mixing with AC (2 or 30 min), a total 30-min mixing of PEs with sediment was ensured for all sediment columns to have the same duration of PE-sediment mixing. After mixing, the sediment was transferred into two Pyrex glass columns (4-inch in length and 1 5/8 inch in inner diameter) capped with Teflon lids to provide duplicate samples for each scenario. Glass filter paper (1.5 μm pore size, Whatman, Piscataway, NJ) and 5 mm of a clean sand layer were placed at the bottom of the column above the outlet lid to prevent possible leaking of fine sediment particles out of the column.

The sediment columns with a flow were operated as closed systems. The outlet of each sediment column was connected to a 40 mL vial containing PE strips cut in 1 in × 1 in, so possible leaching of low molecular PCBs could be monitored without disrupting the sediment columns during the contact period (Figure 9 (B)). The amount of PCB leaching determined by the PE strips in the vials was negligible compared to the amount in the columns. Effluent from the vial was pumped by a peristaltic pump (Ismatec® Low-Speed, Planetary Gear-Driven, Digital Pump; 24 channel, ColeParmer, Vernon Hills, IL), and returned to the inlet of the sediment column. The flow direction in a column was chosen to be downward, because columns with upward flow conditions often suffered from high backpressure, disintegration of a sediment layer and flow by-pass, and inconsistent flow rates.

At each sampling time (1, 3, 12, 24 months), sediment columns were dismantled, and PE strips were retrieved using tweezers, cleaned, and submitted for further PCB analysis. Remaining sediment was archived at 4°C room.

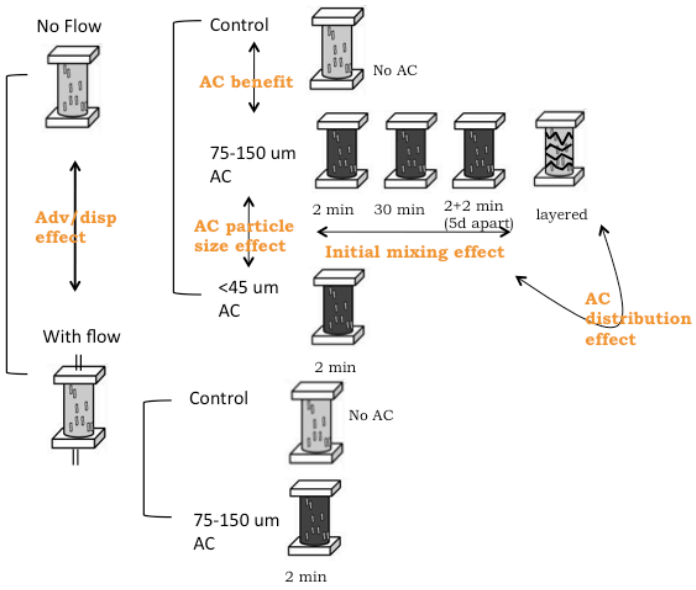


Figure 8. Schematic representation of the sediment column studies.

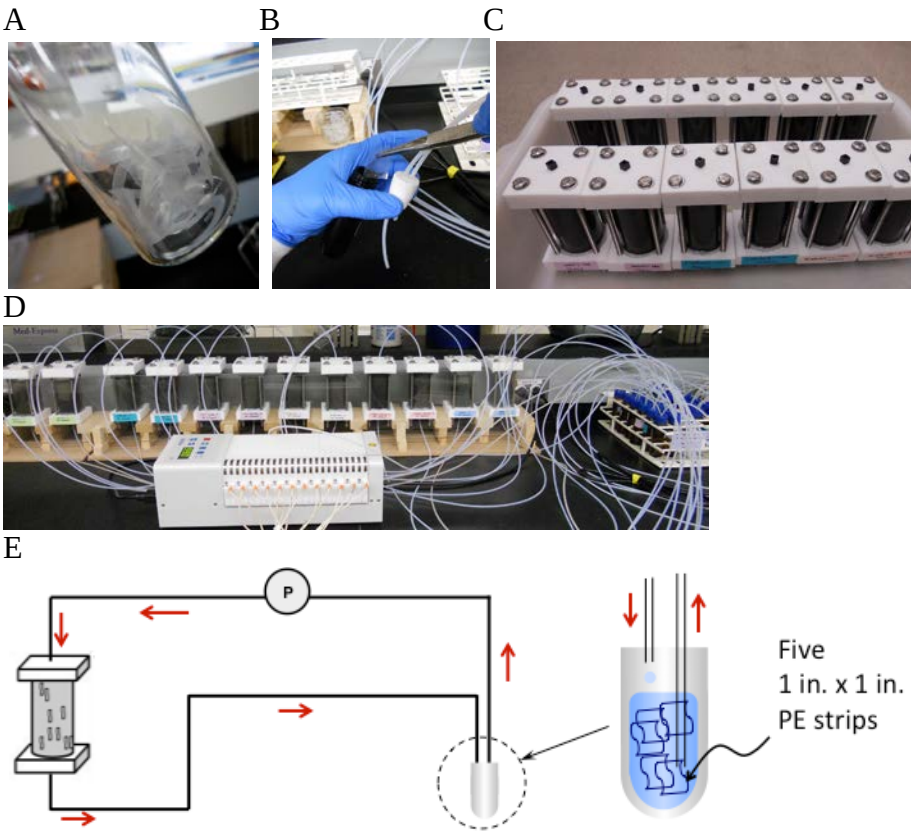


Figure 9. Pictures and schematics of the columns studies. A) PE strips cut in 1/6 in × 1 in to be embedded in the columns; B) placing a PE strip cut in 1 in × 1 in in a 40 mL vial; C) settings for no-flow columns; D) settings for flow-through columns; E) Schematic design of a flow-through column

1.2.3. Model design.

The PCB mass transfer model was modified for the sediment column study by adding an additional phase, PE sampler, into the model. First-order kinetics were used for the PCB uptake into a PE sampler from sediment pore-water as described in Werner et al. (Werner, Ghosh et al. 2006). A differential dispersion coefficient was used for each direction within the column because generally the longitudinal dispersion is larger than the transverse dispersion with respect to the pore-water flow (Freeze and Cherry 1979). Applying these modifications, the overall mass balance equation was written as

$$\frac{dS_{aq}(x,y,z,t)}{dt} = D_x \frac{\partial^2 S_{aq}(x,y,z,t)}{\partial x^2} + D_y \frac{\partial^2 S_{aq}(x,y,z,t)}{\partial y^2} + D_z \frac{\partial^2 S_{aq}(x,y,z,t)}{\partial z^2}$$
$$- \frac{V_{sed}(x,y,z)}{V_{aq}} \cdot \frac{d}{dt}\left[3\int_0^1 q^2 S_{sed\_fast}(x,y,z,q,t)dq + 3\int_0^1 q^2 S_{sed\_slow}(x,y,z,q,t)dq\right]$$
$$- \frac{V_{AC}(x,y,z)}{V_{aq}} \cdot \frac{d}{dt}\left[3\int_0^1 q^2 S_{AC}(x,y,z,q,t)dq\right] - u_z \frac{\partial S_{aq}(x,y,z,t)}{\partial z} - \frac{V_{PE}(x,y,z)}{V_{aq}} \cdot \frac{2k_o}{x_{PE}}\left(S_{aq} - \frac{S_{PE}}{K_{PE}}\right) \quad (3)$$

The variables for the PCB mass transfer model, including Eq. (3) to (6), is defined in Table 8.

Table 8. Definition of the variables for the PCB mass transfer model.

Parameter annotation	Unit	Parameter
S_{aq}, S_{sed_fast}, S_{sed_slow}, S_{AC}, S_{PE}	g/cm^3	Volumetric contaminant concentration in aqueous phase, sediment fast- and slow-releasing fraction, AC, and PE
D_x, D_y, D_z	cm^2/s	Hydrodynamic dispersion coefficients in x-, y-, and z-direction
V_{sed}, V_{aq}, V_{AC}, V_{PE}	cm^3	Volume of sediment, aqueous phase, AC, and PE
k_o	cm/s	Overall mass transfer coefficient for PE-water boundary layer
x_{PE}	cm	PE thickness
K_{PE}	cm^3 water/ cm^3 PE	PE-water partitioning coefficient
C_{AC}	g PCB/g AC	Mass contaminant concentration in AC
M_{AC}	g	Mass of AC in the system
K_{AC_clean}	cm^3 water/ g AC	AC-clean water partitioning coefficient
$D_{eff,AC}$	cm^2/s	effective intra-particle diffusivity of AC

To reduce the computation time for the simulation of the PCB mass transfer in the columns, the system is simplified as a rectangular parallel piped containing sediment, pore-water and AC with a PE sampler (4 × 25 mm as used in the experiments) located in the middle. Further, taking advantage of the symmetry of the system, only the 1/4th corner of the rod-like configuration is taken for model simulation (Figure 10). In this configuration, the model is capable of simulating mass transfer among all the phases (sediment, pore-water, AC and PE sampler) in the column.

Three model compounds, penta- to hepta-chlorinated PCBs, have been selected for the PCB mass transfer model (Table 9). These compounds are chosen to cover the range of mass transfer characteristics of different congener groups and ensure quantifiable detection of the compounds in PE samplers used in the AC-amended columns. The three model compounds are also selected in the long-term field monitoring and modeling study (subtasks 6.2 and 6.3).

Table 9. Selected model PCB compounds.

Congener number	Structure
#101	Penta, 2,2',4,5,5'-
#153	Hexa, 2,2,',4,4',5,5'-
#180	Hepta, 2,2',3,4,4',5,5'-

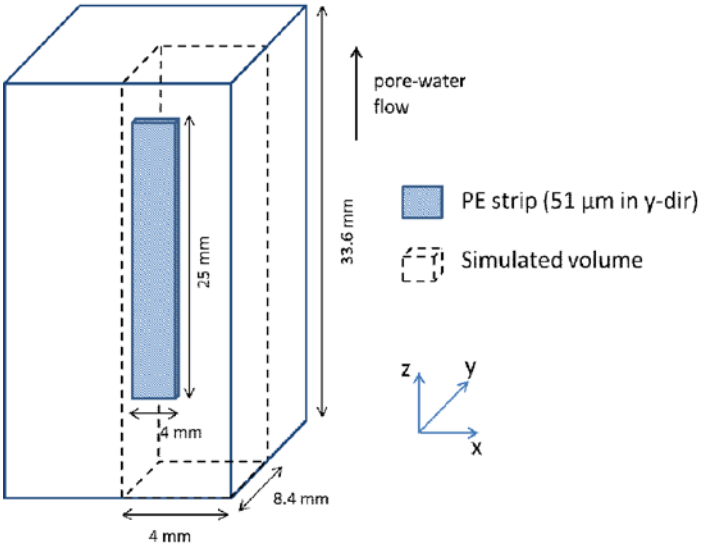


Figure 10. Schematic of a model system.

1.2.4. 14-day aqueous equilibrium test.

Equilibrium distribution of PCBs between sediment and aqueous phases was measured by placing approximately 30 g of untreated wet sediment in 780 mL glass bottles with 30‰ seawater and 1 g/L sodium azide (Extra Pure, EMD) to inhibit microbiological growth and rotating the bottles at approximately 2 rpm on a roller for 14 d. The aqueous samples separated after rolling with the sediment for 14 days for equilibrium were analyzed for PCB concentration (C_{aq}). Colloids were removed using flocculation and centrifugation and PCBs were extracted from the aqueous phase three times with hexane. The remaining sediment in the aqueous equilibrium test was collected and analyzed for PCB concentration to determine the sediment-water distribution coefficients (K_d). Those two parameters were used as model parameters for the PCB mass transfer model.

1.2.5. Desorption test.

The desorption test was conducted to investigate the mass transfer kinetics within sediment particles following the method described by Cho et al. (Cho, Ghosh et al. 2009). The results were fitted to a kinetic model to estimate the fast and slow desorption rates ($rate_{fast}$ and $rate_{slow}$) as well as the fast- and slow-releasing fractions (f_{fast} and f_{slow}) for PCBs. Triplicate 1.0 g sediment samples (dry wt basis) were mixed with artificial seawater (30‰) containing 1 g/L sodium azide to inhibit microbiological growth, and contacted with 1.0 g of Tenax beads (50-70 mesh, Sigma Aldrich). After 1, 2, 3, 8, 16, 28, and 57 days of contact, the Tenax beads were collected and replenished by new beads. PCBs were extracted from the beads by a 50/50 (v/v) hexane/acetone mixture and the extract was analyzed for PCBs.

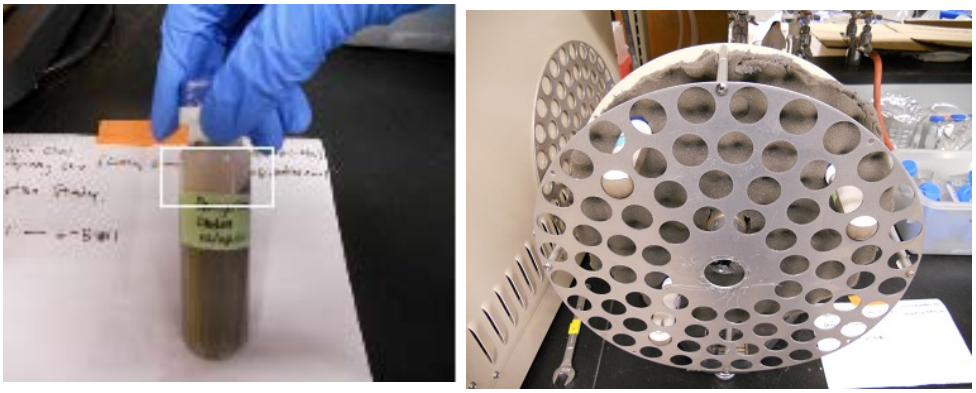


Figure 11. Desorption test settings (left: contact vial that has Tenax beads floated on the top; right: contact vials mounted on a rotator).

1.2.6. Polyethylene (PE) sampler equilibrium test.

PE-water partitioning coefficients (K_{PE}) for 79 PCB congeners and 21 co-eluting PCB congener groups were determined by laboratory experiments. Three 1 in × 1 in PE samplers were loaded with PCBs by mixing with water in a 1-L bottle coated with LMMB PCB stock solution for three months. The PE samplers were then collected and wiped clean to remove any particulate phase. Each PCB-loaded PE sampler was placed in a new 1-L bottle and equilibrated with clean DI water or artificial seawater (30‰) for eleven weeks at 150 rpm (Figure 12). After the contact time, the PE samplers and water samples were collected and extracted to analyze PCB concentrations. The K_{PE} values were calculated as the ratio between concentration in a PE sampler and the aqueous concentration.

Figure 12. Clean artificial seatwater and a PCB-loaded PE strip put in a 1-L bottle to determine the K_{PE} values.

1.2.7. AC sorption kinetics and isotherm test.

The AC sorption kinetics and isotherm tests were conducted using PE samplers pre-loaded with site-specific distribution of PCBs by contacting the samplers with the field-collected sediment. To pre-load PE samplers with PCBs, about 2.0 kg of wet sediment was mixed with 3 L of artificial seawater (30‰) containing sodium azide (1 g/L water) to prevent microbial activity in a 4-L roller bottle. A total of 30 strips of 2.5 cm × 30 cm, pre-cleaned PE strips were added into the bottle, which was then put on a roller with 2 rpm (Figure 13). The PE strips and sediment slurries were then mixed via rotation at 2 rpm for 20 weeks. The PE samplers were retrieved, and stored at 4°C room prior to use. Triplicate PE strips (1 in × 4 in) were taken to determine the pre-loaded PCB concentrations.

Figure 13. PE preloading sample bottles rolling for mixing.

The sorption characteristics of AC were measured using two different AC particle sizes (75-150 μm and <45 μm) in clean water. In a 250-ml amber bottle, one strip of (1 in × 1 in) pre-loaded PE sampler and 10 mg of AC were added, then the bottle was filled with artificial seawater (30‰) containing sodium azide (1 g/L water) to prevent microbial activity. The bottles were mixed on a shaker at 100 rpm and the PEs from triplicate sample bottles for each size fraction were retrieved at 6 and 12 months for PCB concentration. Using the PCB concentration in PE before and after the contact ($S_{PE}(0)$ and $S_{PE}(t)$), the PCB concentration in AC at time t was determined as

$$C_{AC}(t) = \frac{V_{PE}\{S_{PE}(0) - S_{PE}(t)\} - V_{aq}S_{PE}(0)/K_{PE}}{M_{AC}} \quad (4)$$

For <45 μm AC, the concentrations in AC did not increase after 6 months indicating that the system had reached (quasi-) equilibrium. Therefore, the 6- and 12-month data for <45 μm AC were used to determine the AC-clean water partitioning coefficient, K_{AC_clean}, by

$$K_{AC\_clean} = \frac{C_{AC}}{S_{PE}/K_{PE}} \quad (5)$$

To determine the effective intra-particle diffusivity of AC, $D_{eff,AC}$, the results for 75-150 μm AC were fitted with the PCB mass transfer model for a well-mixed system described in Werner et al. (2006):

$$\frac{dS_{aq}(t)}{dt} = -\frac{V_{sed}}{V_{aq}} \cdot \frac{d}{dt}\left[3\int_0^1 q^2 S_{sed\_fast}(q,t)dq + 3\int_0^1 q^2 S_{sed\_slow}(q,t)dq\right] - \frac{V_{AC}}{V_{aq}} \cdot \frac{d}{dt}\left[3\int_0^1 q^2 S_{AC}(q,t)dq\right] - \frac{V_{PE}}{V_{aq}} \cdot \frac{2k_o}{x_{PE}}\left(S_{aq} - \frac{S_{PE}}{K_{PE}}\right) \quad (6)$$

The sediment volume (V_{sed}) was set to zero because no sediment was present in the AC sorption kinetics and isotherm test.

Figure 14. AC particles and a PE sampler (marked white outline to enhance visibility) in a bottle to test the sorption characteristics of AC.

1.2.8. AC fouling test.

AC fouling study was conducted to investigate the attenutation effect by DOM on AC sorption potential for sediment collected from Hunters Point. In a 2-liter jar, about 500 g wet sediment, 4 dry wt% AC, and 30‰ artificial seawater were added. Sodium azide was added to give an aqueous concentration of 1 g/L to prevent microbial activities. The jars then rotated on a bottle roller at 2 rpm. Two size ranges of AC are tested (75-150 μm and < 45 μm), and one control jar was set up as control without AC. Small aliquots of sediment were sampled from each bottle at

1, 6, 12, 18, 24, and 30 months after the initial contact. The sediment slurry samples were divided into three replicates and contacted with clean PE samples in 40-mL vials on a roller for 28 days. After the contact, the PE samplers were retrieved and further analyzed for PCB uptakes.

The concentration of the model PCBs in PE samplers measured at each time point was compared with the PCB mass transfer modeling results for a well-mixed system shown in Eq. (6). The AC-clean water partitioning coefficients (K_{AC_clean}) measured by the AC sorption kinetics and equilibrium test were used as input parameters for the mass transfer modeling.

2. Evaluate possible adverse effects of sorbent-amendments on local invertebrates

2.1. Organisms.

The marine deposit feeder *Neanthes arenaceodentata* was used for exposure tests because it ingests large quantities of sediment/food and is often a marine test organism of choice for sediment assessments. Two-week old *N. arenaceodentata* (culture of Dr. Donald Reish, California State University, Long Beach, CA supplied by Aquatic Toxicology Support, WA, USA) were obtained for these tests. The organisms were acclimatized in silica sand with aerated artificial marine water (31‰ salinity), at 21 ± 1.5 ºC for 10 days while feeding approximately 2 mg ground fish food (®TetraMin) per organisms twice a week. The worms were approximately 42 days post emergence when the bioassays were started.

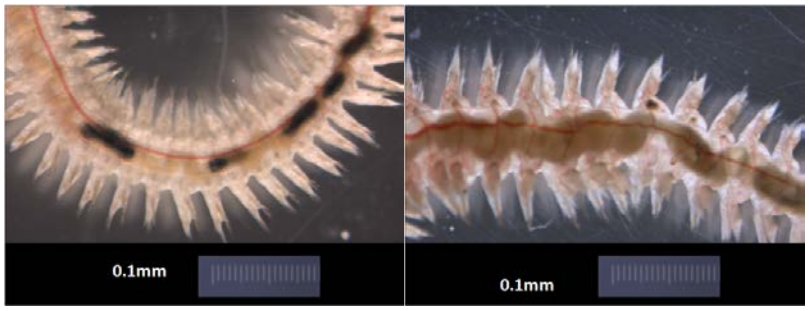


Figure 15. *Neanthes arenaceodentata* and gut content after exposure to sand with activated carbon (left) and sand only (right) (images from dissection-light microscope).

The ingestible particle size for 6-week old organisms was assessed by targeted feeding tests using different size fractions of AC mixed into silica sand and subsequent in vivo and ex vivo analysis of the gut content under a light microscope. Adult *N. arenaceodentata* tested were capable of ingesting AC particles of up to 300 µm. Size fractions larger than 600 µm were not ingested.

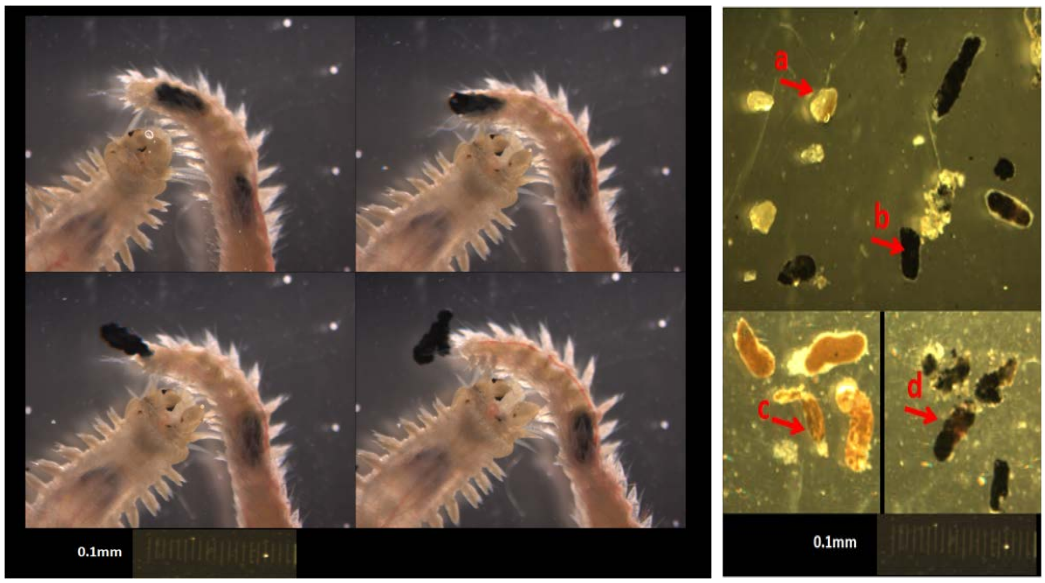


Figure 16. Left: Tracking depuration of feces in *Neanthes arenaceodentata*. Right: Inspection of collected feces after depuration reflects the diet/habitat offered to the organism: (a) white sand; (b) activated carbon, AC; (c) fish food, and (d) AC mixed into fish food (images from dissection-light microscope).

Preliminary tests show that the finest AC (<70 µm) did not mix well when the matrix is pure silica sand and the finest AC particle did not settle. Consequently, exposed organisms were in distress, avoided borrowing, and formed mucus-lined tubes in the aqueous phase. The organisms responded adversely to the physical change of the habitat. However, as confirmed in these and other studies, the finest AC will agglomerate with sediment that contains silt-like particles and in which case the character of the physical habitat is not expected to change significantly.

2.2. Sorbent amendment material.

Coal-derived, virgin AC was employed for the sorbent amendment tests (Calgon, F400). Different AC particle sizes were used to study internal (i.e., ingestible AC) and external effects (i.e., non-ingestible AC) on a benthic organism. Grinding and sieving of the AC obtained a non-ingestible, coarse fraction with 600 µm to 1,000 µm (AC-c), and ingestible size fractions comprising 180 µm to 350 µm (AC-m), and the fine fraction comprising less than 45 µm (AC-f). Details about the properties of this carbon material can be found elsewhere (Zimmerman, Ghosh et al. 2004). The affinity of AC to bind nutrients was tested by contacting AC-c with ground fish food (TetraMin) in de-ionized water for one day. Contacted AC was recovered and rinsed thoroughly with de-ionized water. Virgin AC, fish food and contacted AC were analyzed for total nitrogen (C/N analyzer, Agvise Laboratory, ND).

2.3. Sediments.

Five sediment samples were collected from Holy Island (United Kingdom), Blyth Harbor (United Kingdom), Blackwater estuary (United Kingdom), Hunters Point (California), and

Richmond (California). Sediments were tested for TOC and total nitrogen content (C/N analyzer, Agvise Laboratory, ND). Sediment PCBs and PAHs were extracted following a modified U.S. EPA Method as described by Ghosh et al. (2003). Briefly, sediment samples were extracted using an acetone-hexane mixture (1:1) with sonication and passed through a silica gel column to remove organic interferences. An Agilent model 6890 gas chromatograph with micro electron-capture detector (GC-μECD) was used to analyze for 121 PCB congeners or co-eluting congener groups. Sixteen EPA priority PAHs were analyzed using a gas chromatograph (Agilent model 6890)-mass spectrometer (Agilent model 5973N) in selective ion monitoring mode.

2.4. Sediment amendments.

Exposure tests were conducted with sediment amendments and silica sand with different AC doses and particle sizes as well as in the presence and absence of additional food. First, all five sediments were amended with a high dose of 20% (by dry weight) with non-ingestible AC-c, ingestible AC-m, and silica sand. Additional tests were conducted with Hunters Point (polluted) sediment and the reference sediment from Blackwater to assess influences of finer AC, lower AC dose, and addition of food during exposure.

Portions of these treatments (approximately 0.5 kg) were contacted over 21 days with mixing (manually, three times each week). After contacting, 20 g (wet weight) were placed into 20 mL borosilicate vials with 24 to 30 replicates for each sediment treatment. Additionally, 150 vials were prepared with 20 g silica sand for starvation experiments. The vials were submerged in tubs (10 vials per tub) with aerated artificial marine water (31 ‰). The vials were individually covered by stainless steel mesh (0.101 mm^2 openings), which were fixed with open-top screw caps to allow exchange of water while preventing organisms from leaving the vials during bioassays tests. After one day, the water was exchanged from the tubs before bioassays were started.

2.5. Bioassays and endpoints.

The bioassays employed single organism exposure for 21 days to the different sediments and sediment treatments. Initial wet weights were recorded after 2 days of depuration in seawater for all organisms (N=1200). Initial weights that deviated by more than ± 2 SD were excluded. The worms were assigned to exposure groups strategically to obtain similarly distributed weights across groups. A reference group for analysis of pre-exposure conditions was included. Each exposure group consisted of 24 to 30 worms that were each placed into an individual exposure vial. The water in the exposure tubs was aerated and exchanged twice a week during exposure.

The influence of food supply during exposure was evaluated in addition to the different sediment amendments. Fish food was supplied to additional exposure setups with Hunters Point and Blackwater sediment without amendment and with 20% AC-m, 5% AC-m and 5% AC-f (ground TetraMin®, 2mg per organism, twice a week). Response to feeding was also tested during exposure to silica sand.

After 21-day exposure, organisms were recovered by gentle sieving and depurated in artificial marine seawater (31 ‰) for 48 hours (inspection of cleared gut content). Organisms exposed to silica sand without feeding were retrieved after 4, 11, 21, and 28 days. Depurated

organisms were individually weighed (wet), frozen in liquid nitrogen, and stored at -80 ºC until tissue analysis.

2.6. Tissue analysis.

Tissues were analyzed for total lipid, protein, and glycogen tissue content (N=4 to 6) using one whole organism per test. Total lipid contents were analyzed with a spectrophotometric method as described by van Handel (Handel 1985). Tissue was homogenized with in 500 µL chloroform:methanol (50:50 V/V) in micro centrifuge tubes, centrifuged (2000×g, 5 min) and 100 µl supernatant was transferred to a borosilicate culture tubes. The solvent was evaporated (heating block, 100 ºC), cooled to room temperature, 250 µL concentrated sulfuric acid were added, and solution was heated for 10 minutes at 100 ºC (heating block). After the solution cooled to room temperature, 4.8 mL vanillin reagent (Merck, 1.2 g/L in phosphoric acid (85%): deionized water, 4:1,V/V) was added and absorbance was measured after 25 to 30 minutes at 525 nm (Beckman DU®-64 Spectrophotometer) when the signal was constant. The results were related to lipid concentration by a calibration derived from soybean oil (Sigma-Aldrich®).

Total protein content was measured by bicinchoninic acid (BCA) employing the Pierce® BCA Protein Assay Kit (ThermoScientific®). Organisms were homogenized on ice in 400 µL T-PER Extraction Reagent (ThermoScientific®) and centrifuged (20,000×g, 5 min). Supernatant (100 µL) was incubated for 30 min at 37 ºC in the assays working solution and absorbance was measured at 562 nm. The results were related to protein concentrations relative to calibration with albumin standards (Pierce® BCA Protein Assay Kit by ThermoScientific®).

Total glycogen content was measured utilizing phenol and sulfuric acid as described elsewhere (Taylor 1995). Tissue samples were homogenized on ice in 600 µL de-ionized water and heated for 5 minutes in a 90 ºC water bath to inactivate any enzyme activity. After centrifugation (20,000×g, 5 min) 50 to 400 µL of the supernatant, depending on the total wet weight of the sample, were placed into borosilicate culture tube, volumes were adjusted to 700 µL with de-ionized water and 1.8 mL sulfuric acid (95%) were added. After a reaction time of exactly 2 min, samples were cooled to room temperature in a water bath (20 ºC, 2 min), and 40 µL phenol (90%, pH 6.6/7.9, VWR international Ltd., Poole, England) was added. Absorbance was measured at 480 nm after 30 to 45 min. The results were related to total glycogen concentrations using a calibration with oyster glycogen (ThermoScientific®, Fermentas Molecular Biology Tools). Results were compared by ANOVA testing and post hoc multi comparison tests (Microsoft Excel XLStat, ©1995-2011).

V. Results and Discussion

1. Mass transfer modeling and long-term effectiveness (Task 6)

1.1. Long-term field monitoring and initial model development of the mass transfer of polychlorinated biphenyls in sediment following pilot-scale *in-situ* amendment with activated carbon (Tasks 6.2 and 6.3)

1.1.1. AC placement stability in field plot at 5 years post treatment

Five years after AC deployment, the AC-amended plot, "A," retained AC sorbents comparable to the intended target dose of 3.4 dry wt%. The sampling was confined to the left bottom quarter of the test plot because significant portions of the plot were exhausted by previous sampling events. The calculated AC dose was 3.0±1.2 dry wt% for the top 15 cm sediment layer indicating the secure placement of deployed AC for several years in the inter-tidal mudflat of Hunters Point. Although direct comparison is not feasible, this AC dose is similar to the AC doses assessed near the current sampling locations 1 month and 7 months after AC amendment (core 4, 3.2±2.8 dry wt%, (Cho, Smithenry et al. 2007)). This confirms the prediction by Zimmerman et al. (2008), who showed that the mud flat at Hunters Point is slightly depositional, so deployed AC would be stable unless a high hydrodynamic energy event such as an unusually severe winter storm (100 year event) occurs from the south resulting in currents that exceed the sediment's critical shear stress. The other AC-amended plot, "D," also showed the persistency of AC placement three and a half years after its deployment (3.3±1.3 dry wt% AC dose).

1.1.2. Long-term effectiveness of AC amendment

1.1.2.1. *In-situ* PE uptakes and AC dose-response relationship.

Five years after the AC deployment, a clear benefit of AC amendment on the reduction in the PCB uptake was observed for the PE samplers embedded in the AC-amended sediment (Figure 17 and Table C1). For a 3.7% local AC dose, the reduction in PE uptake increased up to 86% and 55% for PCBs 101 and 180 respectively. As a total for eight representative PCBs, the reduction was 73% with 3.7% AC dose. A correlation between the local AC dose and the reduction in the PCB uptake was evident. As shown in Figure 17, a correlation between PE uptake ratio and AC dose was found for all congeners (linear correlation coefficient r^2: 0.98, 0.92, 0.70 for PCBs 101, 153, and 180, respectively). The stabilization effect was greater for the less chlorinated PCBs as expected from the previous laboratory observations (Zimmerman 2004).

To interpret these experimental findings, PCB uptakes by field-deployed PE strips, 5-year post-treatment, were simulated using the PCB mass transfer model (Figure 17, open symbols). The model successfully predicted the reduction in the *in-situ* PCB uptake by PE samplers correlating with the AC dose and the greater benefit of AC for the lesser-chlorinated PCBs. The random assignment of the location of each AC particle in the model algorithm produced a slightly different prediction for each simulation, depending for instance on exactly how many AC particles are located in proximity to the PE samplers. This gives about 8% variance in each model prediction, and explains why the simulated reductions in the PCB uptake of the PE samplers does not increase steadily with an increasing AC dose, but rather shows this trend with some variation between individual data points.

For PCBs 153 and 180 (Figure 17B and C), the predictions aligned well with the measurement with a tendency to under-predict the benefits. The average deviation of the model predictions from the measurements was about 10%, which was comparable to the model prediction variance of 8%. For PCB 101, the deviation was greater (20%), and the model over-estimated the AC benefit. The deviation decreased with increasing AC dose. These observations are discussed further in the section of "Effect of NOM fouling".

1.1.2.2. *In-situ* SPMD uptake and temporal trend.

Monitoring results from 28-day *in-situ* SPMD uptake studies for three PCB congeners are summarized in Figure 18A (solid symbols). During all three post-assessment events, PCB uptake into SPMD samplers was significantly lower in the AC-amended sediment than in the untreated sediment (t-test, $p<0.05$). The extent of the reduction was variable depending on the local AC dose, as determined from cores taken adjacent to the SPMDs. As with the PE uptakes, the less chlorinated PCBs showed larger reductions in SPMD uptakes.

A direct comparison among the time series is not feasible due to variable AC doses at the three SPMD sampling locations. Nevertheless, a temporal enhancement of the benefit was obvious between one month and seven months after AC amendment, especially when considering the lower AC dose of the 7-month post-treatment sampling location (3.5 vs. 4.4%). Between the 7-month and the 5-year sampling times, a further improvement may have been masked by the lower AC dose (2.4%) at the specific location of the SPMD sampling for the five-year assessments, but PCB 180 still showed a further reduction in the uptake by the SPMDs.

The model predictions (Figure 18A, open symbols) mostly fall within the error range of the experimental data, but there are also some notable discrepancies. Especially, it should be noted that model predictions and measurements for PCB 101 were in very good agreement for the 1 and 7-month time points, but deviate significantly for the 5-year assessments (Figure 18A-1), which was observed also from the *in-situ* PE uptake study 5 years after the treatment.

1.1.2.3. *Ex-situ* aqueous phase PCBs and AC sorption strength.

In addition to the *in-situ* passive sampler assessments, *ex-situ* aqueous phase PCB measurements were conducted using the sediment cores collected for the TOC measurements. The results are depicted in Figure 18B as the ratio of aqueous PCB concentration in sediment from the AC-treated plots relative to the aqueous PCB concentration in sediment from the untreated plots. In comparison with the *in-situ* SPMD measurements, the *ex-situ* aqueous phase PCB measurements show much greater benefits for the AC amendment at all sampling time points (e.g., 91% for PCB 101, 58% for PCB 180 at the 1 month sampling point), which suggest slower mass transfer of PCBs to the AC under field conditions at Hunters Point. The field trial at Hunters Point involved only a brief (ca. one-minute) mixing period during the initial AC placement with a tilling device. Otherwise the SPMDs were placed in sediment that was undisturbed except for the action of natural processes such as bioturbation or tidal pumping. The *ex-situ* aqueous PCB measurements, however, included a 2-week mixing period in the laboratory to facilitate the mass transfer. In previous laboratory experiments with continuously mixed HP sediment, aqueous PCB measurements and SPMD assessments showed very similar reductions (Zimmerman, Ghosh et al. 2004). In the present study, the differences between *in-situ* and *ex-situ* assessments

diminished with time, which supports the idea of a kinetic effect. The difference between quiescent *in-situ* SPMD and complete-mix *ex-situ* aqueous PCB measurements does not entirely disappear over the 5-year observation period, and establishing the thermodynamic sorption equilibrium between AC and surrounding sediment particles in the field trial plots at Hunters Point may therefore take longer than the current monitoring period. Our model predicts that one to two decades may be needed to reach the convergence between the two measurements.

Again, the model predictions (Figure 18B, open symbols) were fairly comparable to the measurements reproducing the effect of the degree of chlorination, except for the deviation of PCB 101 for the 5-year time point (Figure 18B-1). Furthermore, the model predicts a temporal trend of increasing reductions for the *ex-situ* aqueous PCB measurements, whereas a slight trend in the opposite was observed in the experiments (Figure 18B). These observations are the basis of the following discussion of the NOM fouling effect.

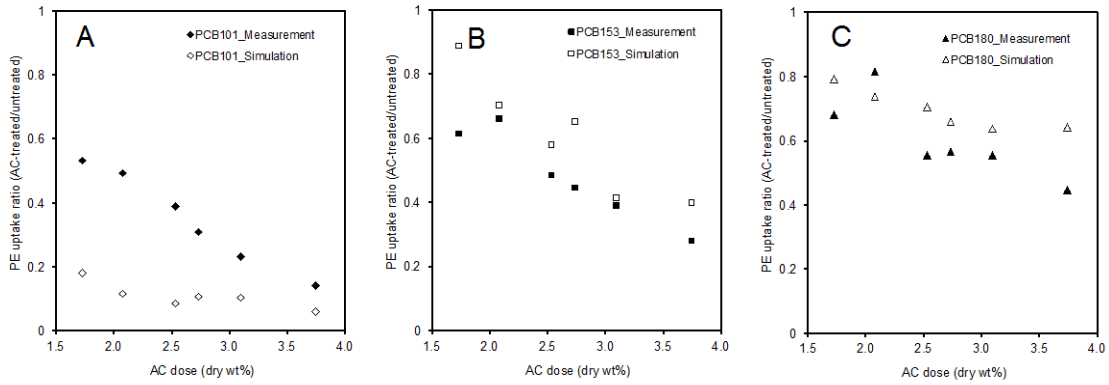


Figure 17. Measured (solid symbols) and modeled (outlined symbols) data for 28-day PE uptakes five years after AC-amendment (single data point) of (A) PCB 101, (B) PCB 153, and (C) PCB 180.

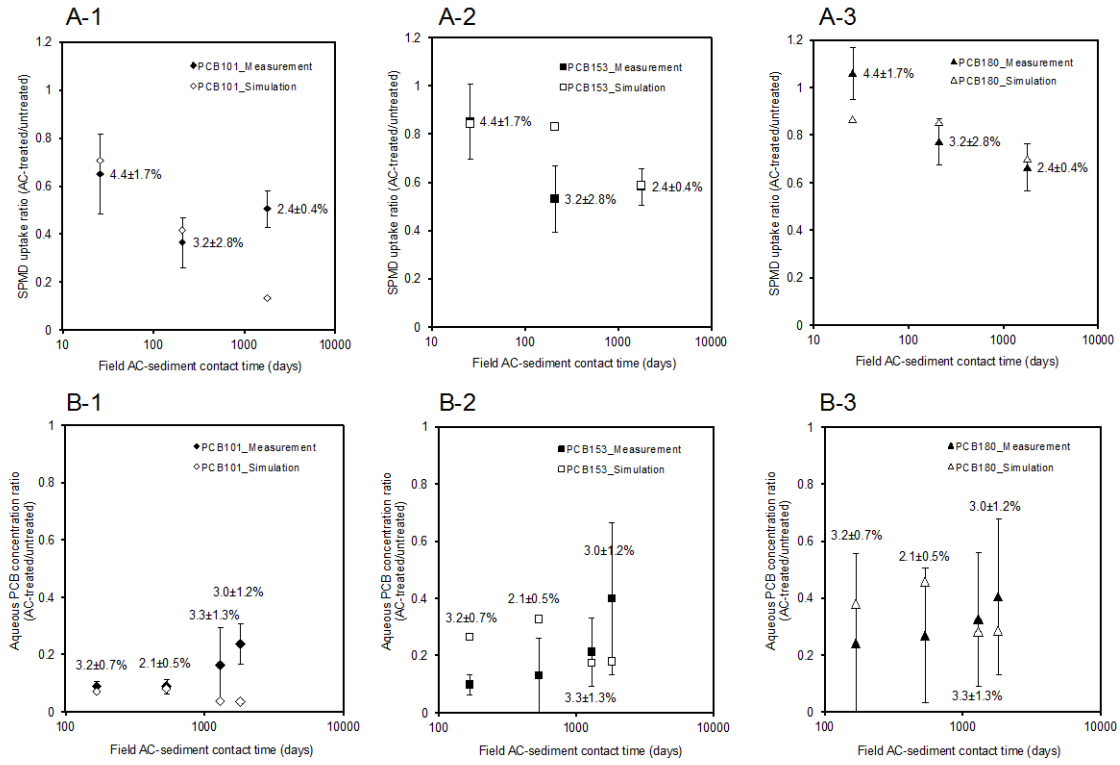


Figure 18. Measured (solid symbols) and modeled (outlined symbols) 28-day SPMD uptakes (A, n=3-5 for measurements) and 14-day aqueous equilibrium PCB concentrations (B, n=3-5 for measurements). All data are represented as a ratio of PCB concentrations of the AC-treated plot to the untreated control plot. Each column represents a PCB congener: PCB 101 (1st column), PCB 153 (2nd column), and PCB 180 (3rd column). The X axes represent logarithmic values of AC-sediment contact time. The data at two earlier time points in each sub-figure were previously reported elsewhere (Cho, Smithenry et al. 2007; Cho, Ghosh et al. 2009). AC doses assesed at each post-treatment monitoringd are shown adjacent to data points (average ± standard deviation).

1.1.3. Effect of field conditions

1.1.3.1. Effect of AC fouling.

When the *ex-situ* aqueous PCB measurement results are compared to the model predictions, all three congeners showed a similar temporal trend with a change from an accurate or under-prediction to an over-prediction of the observed reductions. This trend was most obvious for PCB 101. The model also over-predicted *in-situ* passive sampler uptakes for PCB 101 at the 5-year monitoring point, with larger deviation at the lower AC dose (Figure 17A, Figure 18B-1).

This phenomenon may be due to increased fouling of AC sorbents with time by natural organic matter (NOM) (Newcombe, Hayes et al. 1993). In the model, the attenuation effect was incorporated by invoking adjusted K_{AC} values ($K_{AC\_apparent}$) using previous laboratory data for the site sediment (Hale, Kwon et al. 2010), but this attenuation factor was assumed to be constant

with time. Under field conditions, the mass transfer of NOM from sediment to AC particles would likely be kinetically retarded by the same mass-transfer limitations discussed above for the PCBs. For the early AC-sediment contact period, the fouling effect could be less than estimated from well-mixed batch systems, while at long AC-sediment contact times the effect may be more pronounced and the model would tend to over-predict the AC effect for the later contact period.

The attenuation of the AC sorbent strength could be different at an open field site compared to a closed batch system. In the long-term, there could be an influx of NOM from the surrounding test area such as from overlying water and deposited sediment (Cho, Ghosh et al. 2009). The test plots were situated within a much larger area of untreated sediment, so AC-treated sediment could act as a sink for NOM as well as PCBs and other pollutants originating from the surrounding environment. The NOM exhibits higher concentration, greater mobility, and smaller retardation by sorption process in the aqueous phase compared to PCB molecules (Ding, Snoeyink et al. 2008). In field trials with larger AC treated plots, these effects should be less obvious. Additional NOM could also be formed in intertidal sediment under field conditions, for instance from the decay of algae biomass. Finally, the adsorption of an increasing amount of PCBs and other pollutant molecules by AC could result in greater competition amongst different PCB congeners for the finite number of sorption sites of the AC particles over time.

Field deployed AC still had a considerable sorbent strength and reduced PCB uptake by PE samplers emplaced after 5 years (Figure 17), but the long-term effects and the mechanisms of fouling need to be further evaluated, in particular under field conditions.

1.1.3.2. Effect of advective pore-water movement.

Advective pore-water movement in intertidal or subtidal sediment can occur due to bottom currents, propagating waves, subtidal pumping, bottom water density changes, resuspension of bed sediments, and bottom microtopography (Webb and Theodor 1968; Rocha 2000; Precht and Huettel 2004). These hydrodynamic processes could accelerate the PCB mass transfer from sediment particles to AC particles. The effect of advective pore-water movement was therefore studied with the PCB mass transfer model. In Figure 19A, average pore-water concentrations of PCB 101 in AC-amended Hunters Point sediment were simulated for different advective pore-water velocities: 0, 5, and 50 cm d^{-1}. Previously, the plausible range of average pore-water velocities at the field site was estimated as 0 to 14 cm d^{-1} by an inverse heat transfer analysis (Cho, Werner et al. 2010). Although the inclusion of advection facilitated PCB mass transfer, the effect was not dramatic with a field representative value of 5 cm d^{-1}. However, other systems with higher advective flow, such as upwelling, could facilitate the migration of PCBs from sediment particles to the nearest AC particles (Figure 19A). Burnett et al. (2006) reported that submarine ground water discharges may range from a few sub-centimeters per day to a few meters per day.

1.1.3.3. Heterogeneity of AC amendment distribution.

The heterogeneity of the AC distribution was observed at different scales. The average AC dose of 5-cm long core segments ranged from 0.4 to 4.7% for the AC-treated plots. Heterogeneity also exists at a smaller scale. Millimeter-scale heterogeneities were investigated by sub-

sampling sediment cores with a micro-spatula and measuring the TOC for sediment volumes of approximately 100 mm^3. A representative histogram of the AC dose relative to the average AC dose calculated from the millimeter-scale TOC results is shown in Figure 7B, which shows significant heterogeneity.

To understand the effect of the heterogeneity at a smaller scale, the PCB mass transfer was simulated assuming different spatial heterogeneities of AC distribution at the mm-scale: a) homogenously distributed AC with about 0.2 mm diffusion distance, b) poorly distributed AC with up to a 1 mm diffusion distance, and c) mm-scale heterogeneity in the AC distribution as estimated from mm-scale TOC measurements. Figure 19B depicts the predicted reductions of the *in-situ* PCB 101 sediment pore-water concentration by AC amendment with the same average dose for these three scenarios. As expected, the heterogeneity of AC distribution retarded PCB mass transfer into AC, so the benefit of AC amendment would be delayed. For example, to obtain an average 80% of reduction of PCB 101 in sediment pore-water, it took only one year with a homogeneous AC distribution but six years with poorly distributed AC. The estimated effect of the AC distribution that was inferred based on mm-scale TOC measurements was in between those time values, where it took about 3.5 years to reach 80% reduced PCB 101 sediment pore-water concentration. In the long-term, however, the greatest mass transfer limitation was predicted for the measurement-based AC distribution, which is probably due to a few long diffusion distances between sediment and AC particles in the model system. The poor distribution scenario had a larger, but uniform diffusion distance (1 mm), while the measurement-based scenario had more variable diffusion distances between AC and sediment particles. Therefore, at the early stage, the AC benefit was accelerated for the sediment volumes with short diffusion distances, but in the long term, the benefits from the sequestration process would be retarded by the sediment volumes with long diffusion distances.

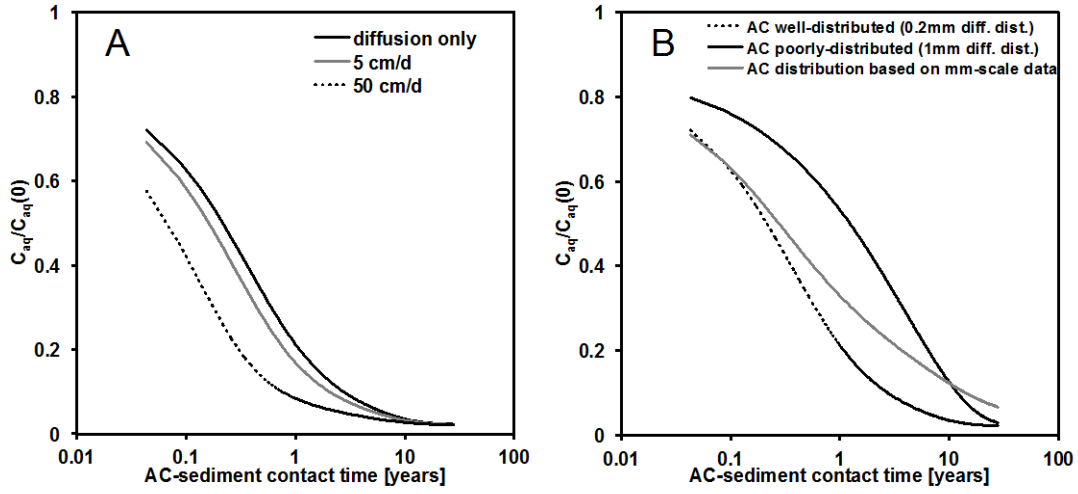


Figure 19. Effect of field conditions on the reduction in the average *in-situ* pore-water concentrations of PCB 101 in AC-treated sediment: (A) effect of advective pore-water movement and (B) effect of variable AC distribution. The X axes represent AC-contact time

(years) and the Y axes represent the ratio of sediment pore-water concentration to the initial concentration. The average AC dose is 3.2 dry wt% in these simulations.

To investigate realistic larger-scale heterogeneity of the AC distribution, two 30-cm sediment cores with different 5-cm average AC dose patterns were selected from the field monitoring sediment samples. A plausible AC distribution was constructed by combining the measured 5-cm average TOC measurements with the micro-scale TOC measurements as illustrated in Figure 20. The vertical pore-water advection velocity was set as 5 cm d^{-1} to study the effect of a plausible advective transport in sediment pore-water. Figure 20A shows the modeling prediction for the *in-situ* pore-water concentration of PCB 101 in sediment (core A2 in Fig. 4 in (Cho, Smithenry et al. 2007)) with a relatively poor homogeneity of the emplaced AC. The coring showed that most of the AC sorbent was deployed within the top 15 cm, while the lower sediment was poorly amended. Model simulations showed discrete benefits for each 5-cm section depending on the AC dose over the 25-year simulation period. A 5 cm d^{-1} advective flow was not sufficient to smooth out the effect of AC heterogeneity. In comparison, Figure 20B shows a more favorable case for AC amendment, where AC sorbents were distributed well (core A4 in Fig. 4 in (Cho, Smithenry et al. 2007)), so PCB 101 availability was reduced more evenly throughout the 5 cm sediment layers. The *in-situ* assessments with the PE samplers (Figure 17) confirm that the benefit of AC amendment depends on the local AC dose and provide further evidence that bioturbation, tidal pumping or similar natural processes were not very effective in homogenizing spatial AC and PCB concentration gradients at the field site.

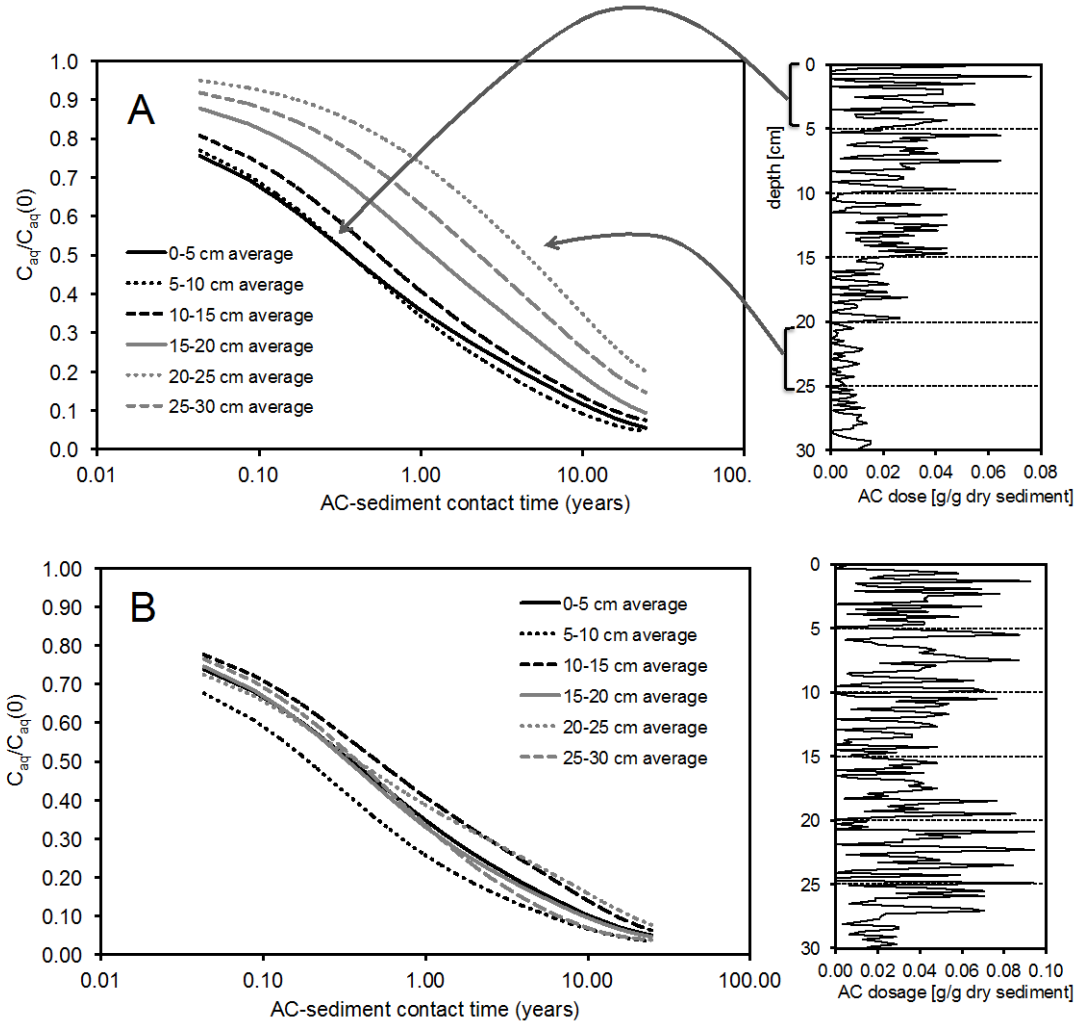


Figure 20. Model simulations of *in-situ* PCB 101 pore-water concentrations in two 30-cm AC-amended cores: A) a core with a relatively poor homogeneity of AC dosing and B) a core with a relatively homogeneous AC distribution. PCB 101 concentrations were averaged for each 5-cm section. The depth profile of AC dose for each core is shown at the right panel. At the graphs on the left side, X axes represent AC-contact time (years) and Y axes represent the ratio of pore-water concentration to the initial concentration.

1.2. PCB mass transfer model enhancement, expansion, calibration, and validation (Tasks 6.3 and 6.4).

1.2.1. Model enhancement and expansion.

1.2.1.1. Model enhancement.

The MATLAB code for PCB mass transfer was reconstructed to reduce model simulation time. By vectorization of three-dimensional matrices, the newly modified code successfully reduced the simulation time up to 8-fold. The long simulation time of the previous model code was a major obstacle for the practical applicability of the model. The enhancement in computation

speed enabled long-term simulation of the PCB mass transfer processes within a much reasonable time frame.

1.2.1.2. User-friendly I/O development.

A user-friendly, beta version of the PCB mass transfer model was developed. The Matlab script was integrated with an Excel I/O file to allow easy and intuitive data input and output. The user can follow instructions shown in the Excel file to enter the site-specific parameters for the model and run the script to obtain modeling results. The results are reported back in the Excel file. Detailed instructions to determine the model parameters are also provided in the Excel file. The output results are shown numerically as well as graphically for easy data examination and export. Using the Excel file, users can easily make use of the model using their site-specific data without any knowledge on use of the Matlab code. The user's manual for the PCB mass transfer model is provided in Appendix C.

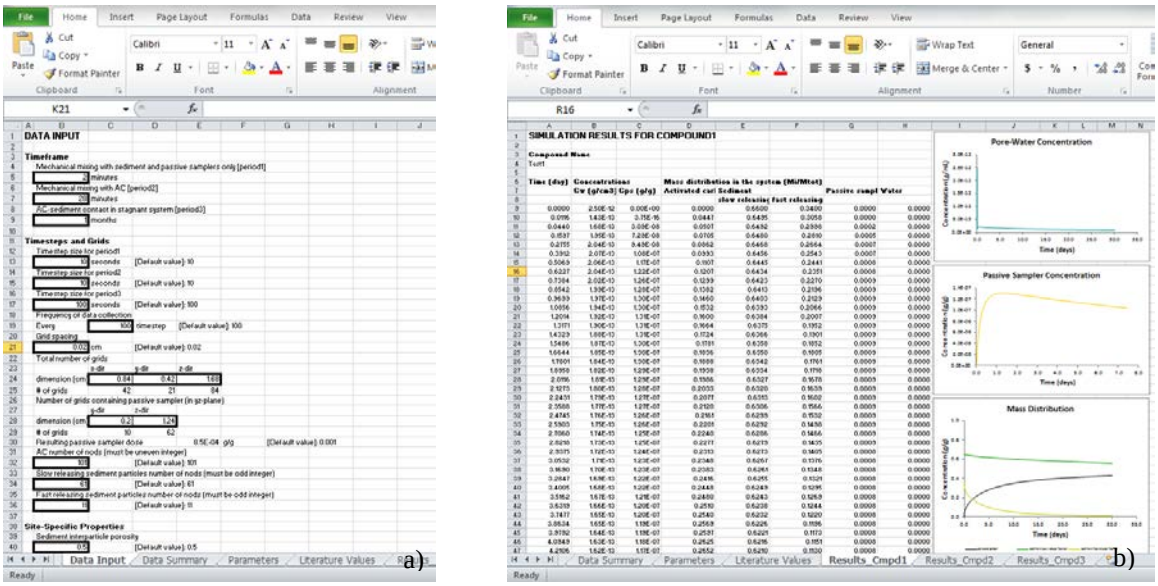


Figure 21. Spreadsheets for a) model parameter input and b) model results of the Excel file in a user-friendly beta version of the HOC mass transfer model

1.2.2. Laboratory measurements.

1.2.2.1. 14-day aqueous equilibrium test.

Equilibrium aqueous concentrations (C_{aq}) and the sediment-water distribution coefficients (K_d) for the model PCBs were determined by the 14-day aqueous equilibrium test. The values are shown in Table 10. The equilibrium aqueous concentrations were used as initial model PCB concentrations in sediment pore-water in the PCB mass transfer model. The K_d values were also used as input parameters for the model.

Table 10. Equilibrium aqueous concentrations (C_{aq}) and the sediment-water distribution coefficients (K_d) measured for the PCB model compounds in this study.

Congener number	C_{aq} (ng/cm^3)	K_d (cm^3/g)
#101	9.2×10^{-4}	3.8×10^{4}
#153	9.4×10^{-4}	9.2×10^{4}
#180	7.3×10^{-4}	1.7×10^{5}

1.2.2.2. Desorption Study.

The desorption test using the Hunters Point sediment sample was conducted to study the PCB release kinetics from the sediment. The test results were fitted to a sediment desorption kinetic model as shown in Figure 22 for the PCB model compounds. The fitted parameters, i.e., the fast and slow desorption rates ($rate_{fast}$ and $rate_{slow}$) and the slow-releasing fractions (f_{slow}, note that $f_{fast}=1-f_{slow}$), are shown in Table 11. The parameters were used in the PCB mass transfer model to simulate the mass transfer between the sediment and the pore-water.

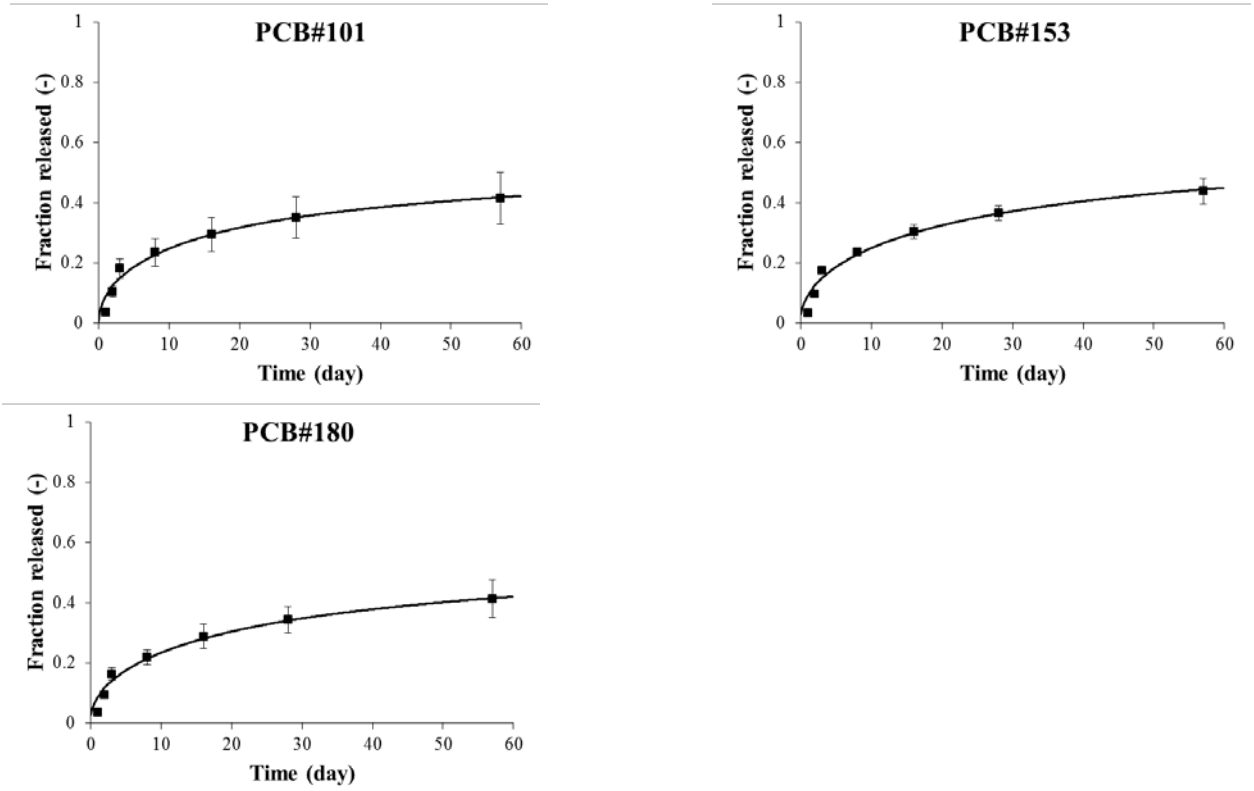


Figure 22. Experimental data and fitting results of the sediment desorption test for the three model PCB compounds. The symbols represent the experimental data and the lines represent the fitting results.

Table 11. Fitted desorption parameters for Hunters Point sediment sample.

Congener number	Fitted parameters		
	$rate_{fast}$ (s^{-1})	$rate_{slow}$ (s^{-1})	f_{slow} (-)
#101	8.80×10^{-8}	1.14×10^{-9}	0.76
#153	6.81×10^{-8}	$1.47\times x10^{-9}$	0.75
#180	6.81×10^{-8}	1.14×10^{-9}	0.76

1.2.2.3. Polyethylene (PE) sampler equilibrium test.

The logarithm of PE-water partitioning coefficients (K_{PE}, cm^3/g) in deionized (DI) water and in artificial seawater with 30‰ salinity for the three PCB model compounds are shown in Table 12. The measured values in DI water were within the range of the literature values for the three compounds. The K_{PE} values in 30‰ artificial seawater were used as input parameters for the PCB mass transfer model.

Table 12. Logarithm of K_{PE} values in DI water and in artificial seawater with 30‰ salinity for the three PCB model compounds.

Congener number	log K_{PE} values[1]		
	Current study (DI water)	Current study (30‰ salinity)	Literature values
#101	6.19 (±0.03)	6.19 (±0.06)	6.18-6.27[a-c]
#153	6.81 (±0.06)	6.73 (±0.01)	6.4-6.81[a-c]
#180	7.20 (±0.10)	7.02 (±0.07)	7.00-7.49[a-c]

[1] K_{PE} values are in cm^3/g.
[a] Fernandez et al. (2009).
[b] Perron et al. (2009).
[c] Smedes et al. (2009).

The K_{PE} values in DI water and 30‰ artificial seawater were measured for a total of 79 PCB congeners and 21 co-eluting congener groups. Because these values are useful for the determination of aqueous PCB concentrations using PE samplers, the numerical values are presented in Table 13. The values in DI water are also plotted against the number of chlorines and the octanol-water partitioning coefficients (K_{ow}) in Figure 23. The K_{ow} values for the PCB congeners were obtained from Hawker and Connell (1988). The PCB log K_{PE} values ranged from 3.87 for PCB#3 (4-chlorobiphenyl) to 7.56 for PCB#206 (2,2'3,3'4,4'5,5',6-nonachlorobiphenyl) and generally increased with the number of chlorines in the molecules. However, the K_{PE} values within the same homolog group varied by up to an order or magnitude because of the effect of the chlorine positioning on the compound structure (Bucheli and Gustafsson 2003; Arp, Breedveld et al. 2009; van Noort, Haftka et al. 2010). Data in Figure 23a show that the K_{PE} values generally decreased with the increase in the ortho-substituted chlorines in the PCB molecules. This can be attributed to the contribution of the ortho-substituted

chlorines on the restriction of the rotation of the two benzene rings relative to each other, which results in decreased hydrophobicity of the molecules. The experimental K_{PE} values in DI water correlated well with the K_{ow} values with the following relationship (Figure 23b):

$$\log K_{PE} = 1.02 \log K_{ow} - 0.451,\ R^2 = 0.926,\ n = 79 \quad (7)$$

Other molecular parameters including the molar volumes and the hexadecane-water partitioning coefficients (K_{hdw}) determined by the SPARC online calculator, and the K_{hdw} values determined by the polyparameter linear energy relationship were also correlated with the experimental K_{PE} values, but those predictors did not show better correlation than the K_{ow} values.

The manuscript that presents outcome of the PE equilibrium test entitled "Polyethylene-water partitioning coefficients for parent- and alkylated-polycyclic aromatic hydrocarbons and polychlorinated biphenyls", authored by Yongju Choi, Yeo-Myoung Cho, and Richard G. Luthy, has been prepared, submitted, and accepted for publication in *Environmental Science and Technology*. The paper is published online at *pubs.acs.org/doi/abs/10.1021/es304566v*.

Table 13. Logarithm of K_{PE} values for 79 PCB congeners and 21 co-eluting congener groups in DI water and 30‰ seawater. Data are shown as average ± standard deviation for triplicate measurements. The K_{PE} values are in cm^3/g.

Congener number	**Measured log K_{PE}**		**Congener number**	**Measured log K_{PE}**	
	DI water	**30 ‰ seawater**		**DI water**	**30 ‰ seawater**
#1	3.87±0.02	4.04±0.04	#136	6.23±0.02	6.15±0.07
#3	4.21±0.03	4.39±0.08	#138	6.66±0.04	6.51±0.06
#6	4.41±0.04	4.57±0.06	#141	6.96±0.06	6.76±0.05
#16	4.72±0.02	4.91±0.05	#146	6.81±0.06	6.70±0.06
#18	4.84±0.03	5.06±0.07	#151	6.52±0.01	6.45±0.07
#22	5.13±0.03	5.32±0.06	#153	6.81±0.06	6.70±0.06
#24	4.84±0.04	5.06±0.08	#155	6.56±0.15	6.61±0.24
#25	4.95±0.06	5.14±0.11	#156	6.52±0.07	6.38±0.11
#26	5.17±0.04	5.37±0.05	#158	6.67±0.03	6.55±0.10
#27	4.85±0.03	5.06±0.07	#163	6.63±0.04	6.51±0.06
#29	5.23±0.02	5.44±0.06	#171	6.76±0.02	6.67±0.10
#32	4.93±0.03	5.14±0.06	#172	6.51±0.13	6.52±0.13
#37	5.43±0.03	5.59±0.05	#174	7.04±0.04	6.79±0.07
#40	5.22±0.03	5.31±0.03	#177	7.07±0.06	6.84±0.07
#41	5.47±0.03	5.60±0.06	#178	6.99±0.06	6.82±0.02

#42	5.34±0.03	5.46±0.05	#180	7.20±0.10	7.02±0.07
#43	5.55±0.02	5.69±0.05	#183	7.14±0.05	6.98±0.04
#44	5.37±0.02	5.52±0.06	#185	6.98±0.06	6.84±0.08
#45	5.18±0.02	5.34±0.07	#192	7.10±0.06	6.98±0.06
#46	5.10±0.02	5.26±0.06	#194	7.41±0.19	7.25±0.09
#51	5.36±0.02	5.53±0.05	#195	7.38±0.14	7.15±0.08
#56	5.66±0.02	5.74±0.05	#197	6.80±0.10	6.83±0.12
#60	5.79±0.02	5.87±0.05	#199	6.83±0.07	6.76±0.12
#63	5.77±0.04	5.85±0.00	#201	7.45±0.15	7.26±0.06
#64	5.54±0.02	5.67±0.06	#202	7.12±0.10	7.09±0.09
#69	5.64±0.03	5.78±0.08	#205	7.15±0.13	7.19±0.10
#71	5.43±0.02	5.57±0.05	#206	7.56±0.28	7.43±0.01
#74	5.61±0.09	5.87±0.08	#207	6.87±0.09	6.93±0.10
#77	5.79±0.02	5.87±0.03	#208	7.05±0.18	7.07±0.12
#81	5.95±0.02	6.01±0.03	#4 + #10	4.14±0.02	4.35±0.06
#82	5.92±0.01	5.88±0.06	#5 + #8	4.60±0.03	4.82±0.07
#83	6.00±0.03	5.95±0.10	#7 + #9	4.57±0.03	4.80±0.09
#85	6.20±0.02	6.16±0.06	#12 + #13	4.71±0.02	4.91±0.08
#87	6.08±0.02	6.05±0.05	#15 + #17	4.95±0.03	5.16±0.07
#89	6.08±0.02	6.14±0.06	#21 + #33 + #53	5.16±0.02	5.35±0.06
#91	5.95±0.05	5.95±0.06	#28 + #31	5.26±0.02	5.45±0.06
#97	6.09±0.03	6.07±0.06	#47 + #48	5.61±0.02	5.76±0.07
#99	6.18±0.04	6.17±0.07	#49 + #52	5.43±0.02	5.59±0.07
#100	5.87±0.03	6.01±0.04	#66 + #95	5.94±0.05	6.10±0.06
#101	6.19±0.03	6.19±0.06	#70 + #76	5.76±0.03	5.85±0.07
#103	6.29±0.11	6.19±0.10	#84 + #92	5.78±.0.02	5.81±0.05
#105	6.44±0.07	6.31±0.08	#114 + #131	6.20±0.02	6.22±0.04
#107	6.12±0.15	6.16±0.27	#123 + #149	6.51±0.03	6.41±0.09
#110	6.07±0.02	6.03±0.06	#124 + #144 + #147	6.59±0.02	6.44±0.04
#118	6.42±0.03	6.35±0.09	#130 + #137 + #176	6.98±0.08	6.80±0.09
#119	5.93±0.05	6.03±0.00	#157 + #200	7.47±0.14	7.47±0.07
#128	6.52±0.01	6.28±0.03	#170 + #190	7.05±0.07	6.84±0.07
#132	6.30±0.06	6.22±0.06	#182 + #187	7.12±0.05	6.95±0.07
#134	6.53±0.10	6.34±0.07	#196 + #203	7.39±0.16	7.28±0.08
#135	6.45±0.01	6.33±0.08			

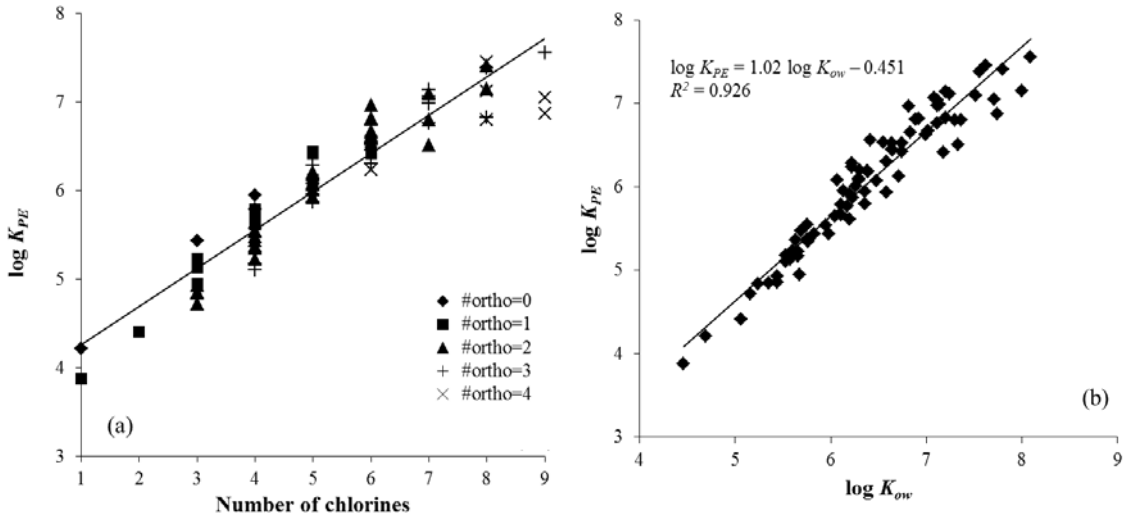
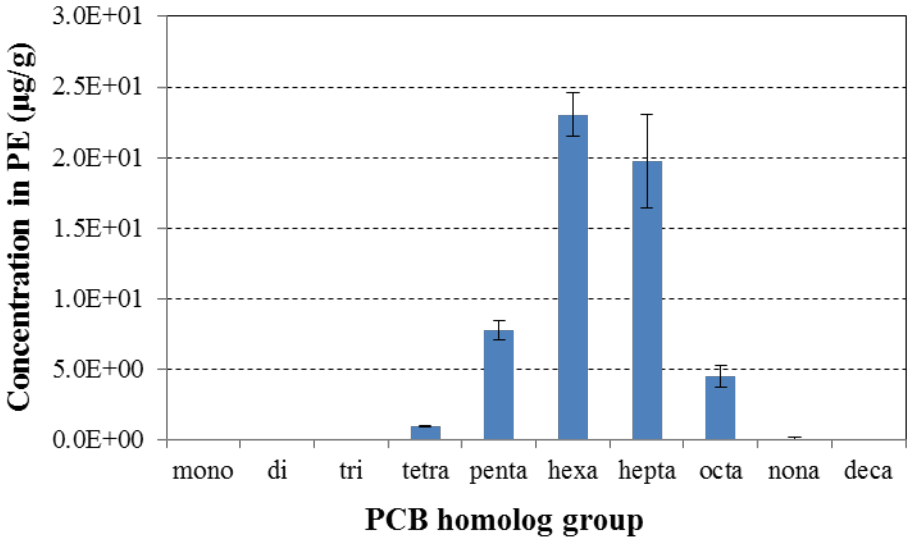


Figure 23. Logarithm of K_{PE} values for 79 PCB congeners measured as single compounds in DI water plotted against (a) the number of chlorines and (b) the octanol-water partitioning coefficients obtained from Hawker and Connell (1988). The K_{PE} values are in cm^3/g.

1.2.2.4. AC sorption kinetics and isotherm test.

The PCB concentration in the pre-loaded PE samplers after 20 weeks of contact with Hunters Point Shipyard sediment has been determined. The total PCB concentrations in the PEs were 56 ± 5 µg/g (average ± standard deviation, *n*=3). As expected, the homolog distribution in the PEs followed the distribution in the sediment sample (Figure 24).



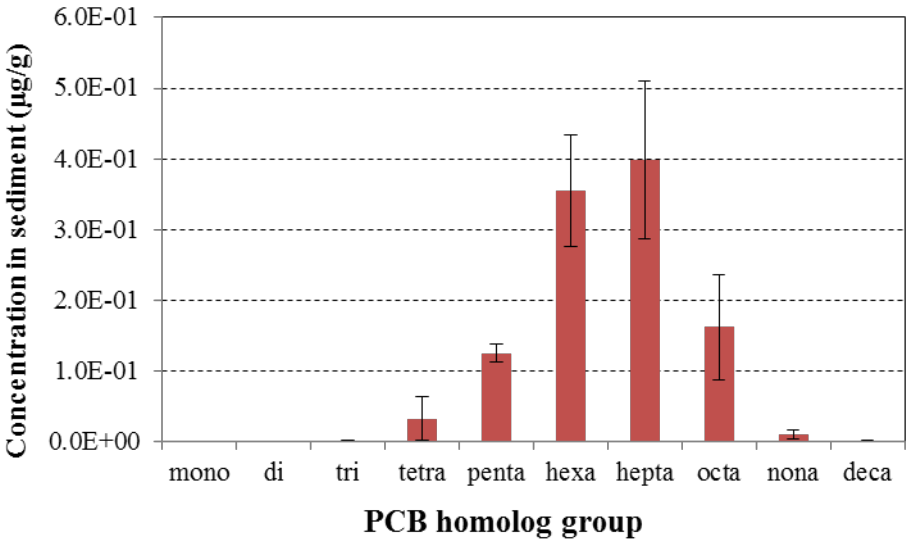


Figure 24. Concentrations of PCBs in pre-loaded PE samplers (top) and the sediment sample (bottom).

Using the pre-loaded PEs, the AC sorption properties for the three model compounds, PCB#101, #153, and #180, were determined as shown in Table 14. The values determined in this study matched well with the literature values. The AC-clean water partitioning coefficients (K_{AC_clean}, cm^3/g) and the effective diffusivity in AC (D_{AC_eff}, cm^2/s) for the PCB model compounds were used as input parameters for the PCB mass transfer model to simulate the column study results.

Table 14. AC sorption properties measured for the PCB model compounds in this study.

Congener number	**log K_{AC_clean} [1]**		**$D_{AC,eff}$ (cm^2/s)**	
	Measured	**Literature**	**Measured**	**Literature**
#101	9.10	9.05[a], 9.18[b]	1.7×10^{-15}	1.2×10^{-15} [c]
#153	8.94	-	2.9×10^{-15}	2.0×10^{-15} [d]
#180	9.17	-	2.8×10^{-15}	1.2×10^{-15} [d]

[1] K_{AC_clean} values are in cm^3/g.
[a] Jonker and Koelmans (2002).
[b] Hale (2009).
[c] Werner et al. (2006).
[d] Regressed using a model provided in Werner et al. (2006) and the experimental K_{AC_clean} value measured in this study.

1.2.2.5. AC fouling tests.

The experimental results for the AC fouling test after 1.5, 6, 12, 18, 24, and 30 months of AC-sediment contact in a well-mixed slurry are shown in Figure 25. The PCB mass transfer modeling results using K_{AC_clean} determined in this study are also plotted in the figure for comparison. The experimental and modeling results suggest that the AC performance for the model compounds was not attenuated by the presence of DOM in the sediment slurry. The experimental results of 28-day PE uptake were close or even smaller than the modeled values at all time points. These observations are opposed to the results in Werner et al. (2006), who reported that the experimental SPMD uptake for PCB#101 and #118 was a factor of 2.4 - 6.5 greater than the modeled uptake using Hunters Point sediment. In this study, the K_{AC_clean} values were measured with a site-specific distribution of PCBs in sediments, while Werner et al. (2006) used the literature values as input parameters. Therefore, as opposed to Werner et al. (2006), the competitive effect between the PCB congeners present in the study sediment was taken into account in the K_{AC_clean} values for the model calculation. Although further AC attenuation effects may be possible in the sediment slurry by the presence of sediment DOM, the fouling study results showed that this effect was not pronounced at least for our study sediment. Because it was verified that AC sorption properties were not attenuated by DOM or other interferences, no correction in the AC sorption capacity by AC fouling effect was made for the PCB mass transfer model.

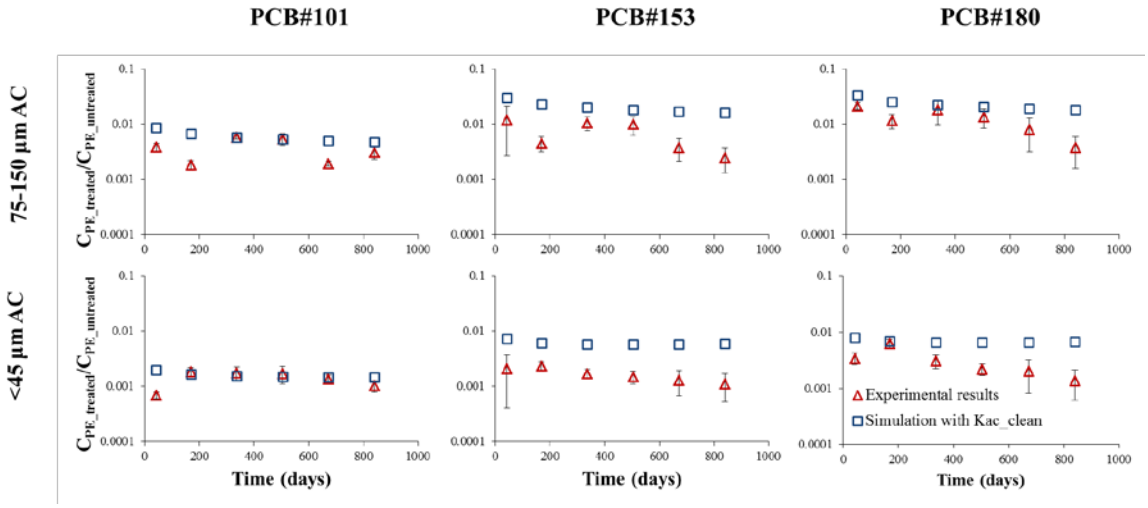


Figure 25. Comparison of experimental results and simulation results with K_{AC_clean} values for the AC fouling study. Data are reported as ratio of 28-day PE uptake in AC-treated samples (4 dry wt%) and untreated (no AC) samples ($C_{PE\_treated}/C_{PE\_untreated}$). The error bars represent standard deviation of triplicate measurements.

1.2.2.6. Column Studies.

The results of the sediment column studies with different AC application scenarios after 1, 3, and 24 months of sediment-AC contact under no-flow conditions are shown in Figure 26. The results

for the 12-month, no-flow columns are not reported because of the possibility of an experimental error during sample processing. The differences between replicates were less than 20% for most cases, verifying the reproducibility of the experimental procedure applied in the study. A significant benefit of AC addition was observed for all columns with AC-mixed sediment (AC dose = 4 dry wt%). After 1 month, 70-86% reduction in total PCB uptake in PE was observed with variation in the effectiveness for different AC application scenarios.

At each sediment-AC contact time, the following differences among the different AC mixing regimes, particle sizes, and distribution were consistently observed: i) greater benefit of AC treatment with smaller AC grains (75-150 μm AC versus <45 μm AC with 2 min mixing), ii) greater benefit by increased initial mechanical mixing period (2 min mixing versus 30 min mixing with 75-150 μm AC), iii) no enhancement in the effectiveness by re-mixing the sediment with AC 5 days after the initial mixing (2 min mixing versus 2×2 min mixing with 75-150 μm AC), and iv) little or no benefit of AC treatment by layered AC application.

In the AC-layered columns, 75-150 μm AC with 4 dry wt% dosing was applied as layers with 2 cm spacing, so the diffusion distance for PCBs was 0.5 cm on average with a maximum of 1 cm. For the AC-mixed columns, the estimated average diffusion distance was in the order of sub-mm for 75-150 μm AC assuming homogeneous distribution. The millimeter-scale AC dose measurements conducted in our parallel study verified that 2 minutes of mechanical mixing between AC and sediment were enough to homogeneously distribute AC into the sediment matrix for the column studies. Because of the longer diffusion distance for the AC-layered columns, much longer time is required for contaminants in sediment to reach AC, resulting in retarded response to AC treatment compared to the AC-mixed columns. The results of the column studies show that two years of stagnant contact were not sufficient to achieve a distinct benefit of AC treatment with a diffusion distance in the order of a centimeter for PCBs.

The column study results showed a slightly better effectiveness for 30 min mixing compared to 2 min mixing (two-way ANOVA, $p<0.05$). For example, the reduction in total PCB uptake in PE compared to the no-AC controls was increased from 70% to 83% at 1 month by increasing the initial mixing time from 2 min to 30 min. Since homogeneous distribution of AC into the sediment matrix was achieved by 2 min mixing, the difference can be attributed to the facilitated contaminant mass transfer during the mixing process. When AC is mechanically mixed with sediment, direct contact between AC and PCBs in sediment is achieved, which results in much faster PCB mass transfer kinetics from sediment to AC than for stagnant AC-sediment contact. On the other hand, the difference between the results for 2 min mixing and 2×2 min mixing (i.e., two times of 2 min mixing with 5 days apart) columns were not statistically significant (two-way ANOVA, $p>0.1$). Since the contaminant mass transfer process is a relatively slow process under stagnant condition, it is likely that 5 day interval between the two mixing events was not sufficient to obtain significant benefit of AC particle redistribution. It is likely that at least months of interval between the mixing events are required to achieve the beneficial effect of AC-sediment remixing. Laboratory or pilot-scale studies are needed, however, to demonstrate the effect of the multiple mixing events with longer time intervals than were applied in this study.

The benefit of AC treatment was more readily observed for columns with <45 μm AC than those with 75-150 μm AC. For example, the 2 min mixing, <45 μm AC columns showed 86% reduction in total PCB uptake in PE at 1 month, while those with 2 min mixing, 75-150 μm AC showed 70% reduction. Two factors have been suggested to contribute to the better effectiveness of AC treatment for smaller AC grains in well-mixed condition: i) the faster diffusive mass transfer within the particles and ii) the smaller fouling effect by DOM or other interferences, because of the greater external surface (Werner, Ghosh et al. 2006; Choi, Cho et al. 2013). In addition, the shorter diffusion distance for contaminants in sediment to AC may contribute to the improved benefit of AC treatment in a stagnant sediment (Hale and Werner 2010). Assuming uniform distribution of AC particles in a sediment layer, the average diffusion distance is inversely proportional to AC particle size because more AC particles are present for smaller particle size at the same AC dose. The results of the column studies in this study are the first experimental demonstration of the AC particle size effect on the effectiveness of AC treatment under stagnant AC-sediment contact.

The effect of stagnant AC-sediment contact time on the effectiveness of AC treatment was evident for all AC application scenarios. For columns with 2 min mixing, 75-150 μm AC, the reduction increased from 70% at 1 month to 78% at 3 months, and to 93% at 24 months. After 24 months, all AC-mixed columns showed greater than 93% reduction for total PCBs. These results verify that the effectiveness of AC treatment improved with time and that a significant benefit of the treatment (e.g., an order of magnitude or greater reduction in passive sampler uptake) can be achieved under stagnant AC-sediment contact within a reasonable time period.

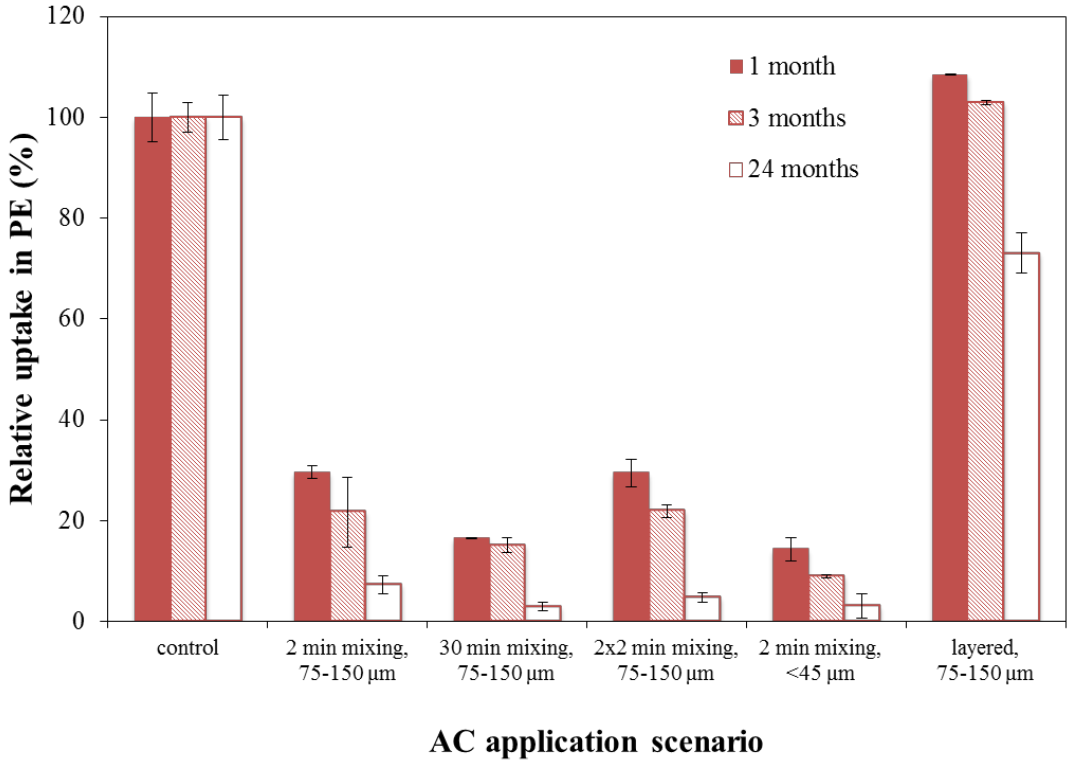


Figure 26. Results of no-flow column studies shown as relative uptake in PE (%) compared to the no-AC controls for total PCBs. The error bars represent the difference between the duplicate columns.

The results for the column studies with 2 min mixing, 75-150 µm AC at 1, 3, and 24 months are shown by PCB homolog groups in Figure 27. The results show that the less chlorinated compounds responded more readily to AC treatment than the more chlorinated compounds. For tetra-chlorinated biphenyls, most benefit of AC treatment was achieved within 1 month of AC-sediment contact, while the benefit improved significantly with time for more chlorinated congener groups. In addition, the effectiveness of AC treatment was generally greater for the less chlorinated congeners for up to two years of AC-sediment contact because of the faster mass transfer kinetics as pointed out in the previous studies (Zimmerman, Ghosh et al. 2004; Werner, Ghosh et al. 2006). The less chlorinated PCB congeners exhibit faster release from sediment, faster migration from sediment to to the surface of AC, and faster diffusion through the AC particles, all contributing to the faster response to AC treatment than the more chlorinated congeners (Werner, Ghosh et al. 2006; Hale and Werner 2010). The results of the column studies clearly show that the differential kinetics for different PCB congener groups significantly affect the short-term effectiveness of AC treatment. This indicates that the congener distribution should be taken into account to characterize or predict the overall effectiveness of AC treatment for PCBs.

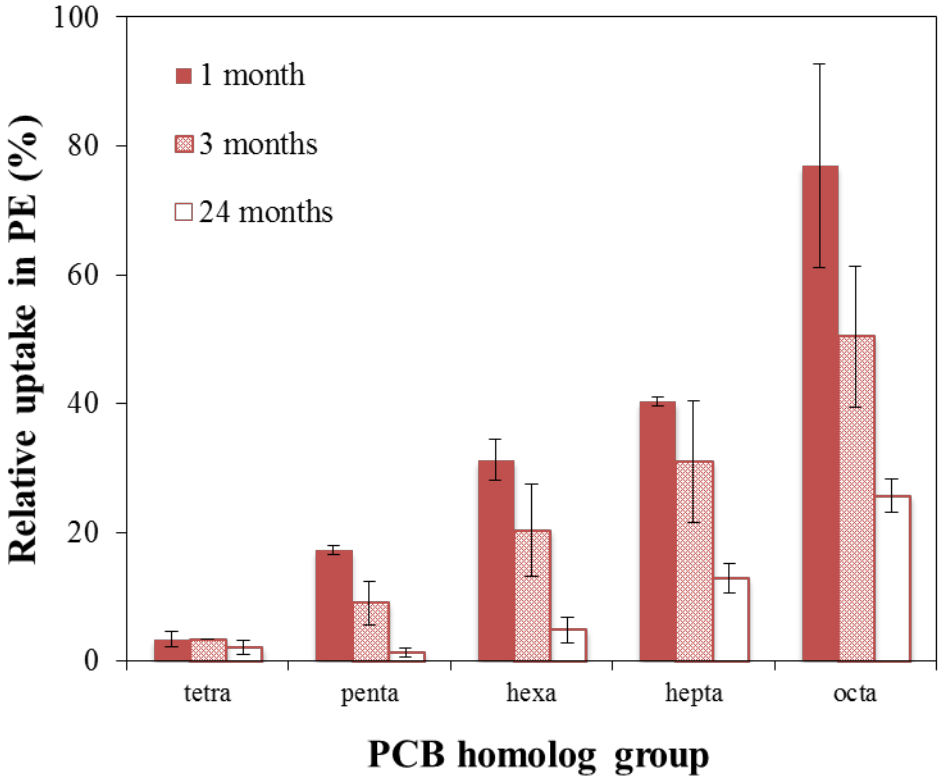


Figure 27. Results of no-flow column studies with 2 min mixing and 75-150 μm AC for PCB homolog groups (AC dose = 4 dry wt%). The error bars represent the difference between the duplicate columns.

The results for flow columns with 5 cm/d pore-water flow as Darcy's velocity are shown in Figure 28 and Figure 29 along with the results for no-flow columns. As was observed in the no-flow columns, the flow columns showed substantial reduction in uptake in PE for both sediments compared to the no-AC controls. After 1 month, 67% reduction in total PCB uptake in PE was observed. The flow columns with 2 min mixing, 75-150 μm AC show a gradual enhancement in benefit of AC treatment with time, substantiating the effect of AC-sediment contact time on the effectiveness under pore-water movement. After 24 months, the reduction in total PCB uptake in PE went up to 91%.

The effect of pore-water movement was not evident for all column studies (Figure 28 and Figure 29). The reductions in relative contaminant uptake in PE for the flow and no-flow columns were within 10% difference for 2 min mixing, 75-150 μm at 1 and 24 months and for all application scenarios at 3 months. The AC-layered columns under flow condition at 3 months did not show any improvement in the effectiveness compared to those under no-flow condition. This suggests that the pore-water movement at 5 cm/d did not significantly contribute to overcoming the heterogeneity of AC distribution by the advection-facilitated mass transfer of PCBs. These results are in line with the long-term PCB mass transfer modeling results discussed in Section 1.1, which showed only a slight improvement in benefit of AC treatment (<5% of

initial pore-water concentration) by advection-facilitated mass transfer for PCB#153 for contact times up to 25 years.

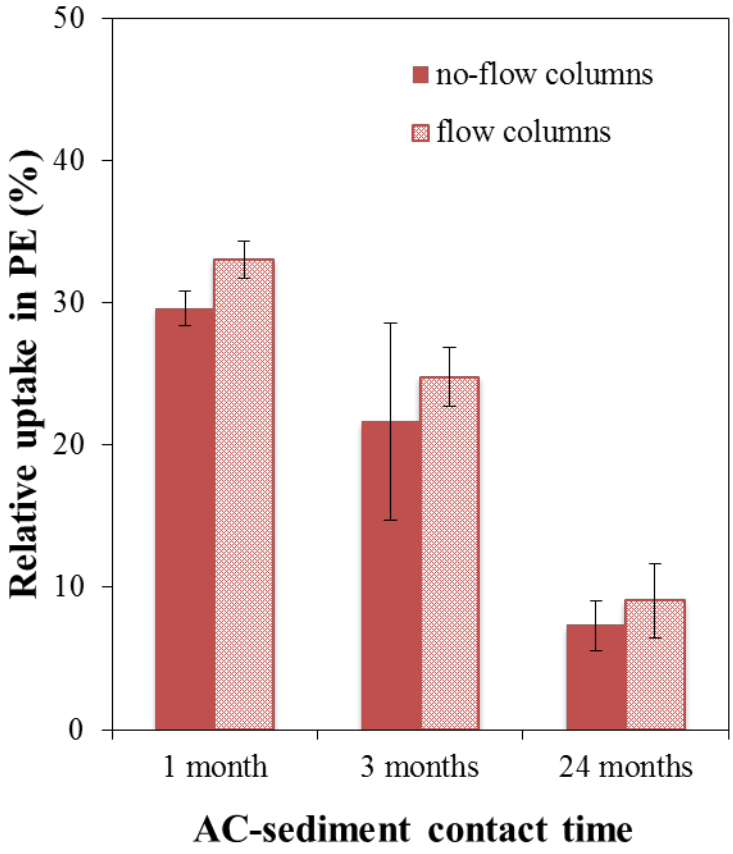


Figure 28. Comparison of no-flow and flow columns for 2 min mixing and 75-150 μm AC at 1, 3, and 24 months. The error bars represent the difference between the duplicate columns.

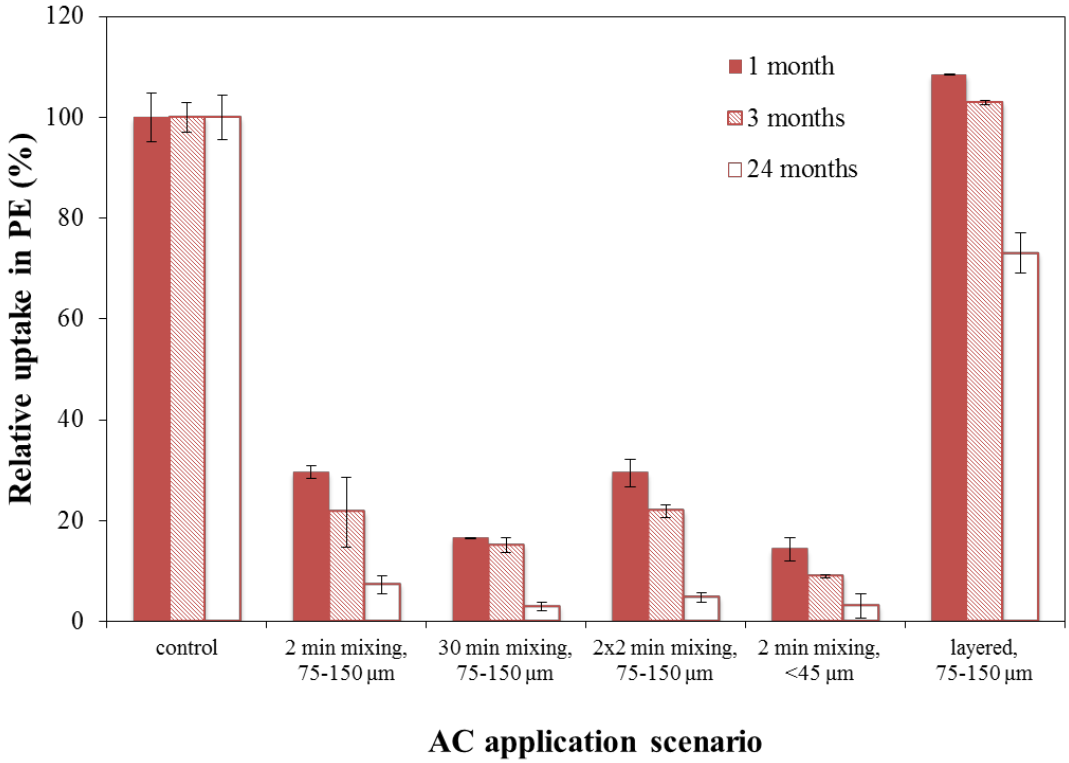


Figure 29. Comparison of no-flow and flow columns for different AC application scenarios at 3 months. The error bars represent the difference between the duplicate columns.

1.2.3. Model Validation.

1.2.3.1. Model Validation with Column Study Results.

The modeling results for the sediment column studies with 2 min mixing, 75-150 µm AC, no pore-water movement are compared with the experimental results in Figure 30. The results are shown as PE concentration in the AC-treated columns ($C_{PE,treated}$) relative to PE concentration in the no-AC controls ($C_{PE,untreated}$). The increase in the effectiveness with time and the relative difference between the different model PCBs observed in the experiments were well reproduced in the modeling results. The effectiveness of treatment for the model PCBs decreased with the increase in the number of chlorines in the PCB molecule because of the slower mass transfer process for the highly chlorinated congeners.

The modeling results consistently underestimated the effectiveness of AC treatment, however, compared to the experimental results. The modeled ratio of $C_{PE,treated}/C_{PE,untreated}$ for the model PCB compounds were factors of 2-3 greater than the experimental values at 1 month and factors of 3-8 greater at 24 months. The data indicated that the mass transfer kinetics in the experiments were faster than expected by the mass transfer model. The mass transfer process occurring in the AC-amended sediment can be divided into three stages: i) the contaminant desorption from sediment, ii) the sorption-retarded transport of the contaminant from sediment to

AC through sediment pore-water, and iii) the uptake of the contaminant by AC. The kinetic parameters in the model for sediment desorption and uptake by AC were determined by batch experiments in this study, and it is unlikely that the stagnant sediment packed in columns exhibited faster kinetics for those processes. Therefore, the most plausible explanation for this systematic underestimation of the effectiveness of AC is that the kinetics of PCB transport between sediment and AC was faster than predicted by the model, which can be attributed to DOM-facilitated transport of the compounds. The mass transfer model accounts only for the transport of freely-dissolved molecules while a large fraction of compounds may be transported in DOM-associated form, resulting in higher mobility in sediment pore-water (Magee, Lion et al. 1991; Johnson and Amy 1995). The inclusion of the DOM-facilitated PCB transport into the model is challenging, however, because it requires the site-specific characterization of the interactions between DOM and PCB molecules and the diffusive mass transfer of DOM in sediment pore-water.

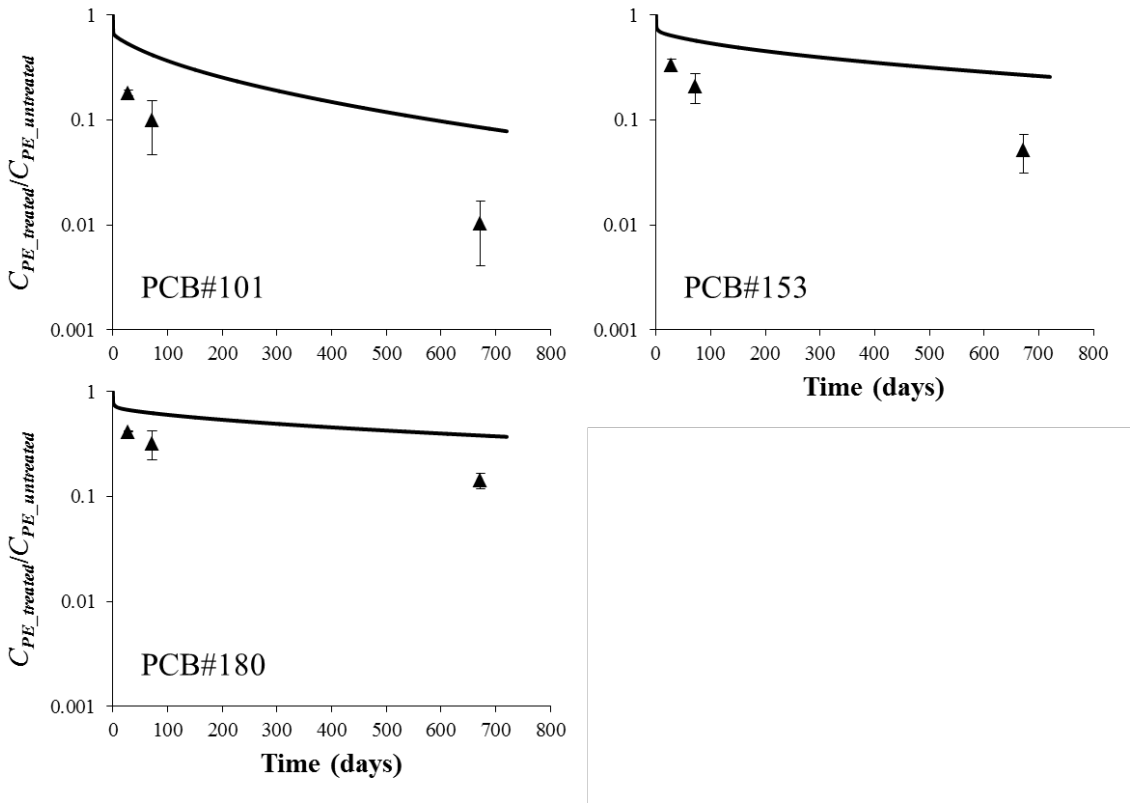


Figure 30. Comparison between the modeling and experimental results for sediment column studies with 2 min mixing, 75-150 μm AC (AC dose = 4 dry wt%), and no pore-water movement for the model PCBs in HP sediment. The error bars represent the difference between the duplicate columns.

The mass transfer model was run for different AC application scenarios tested in the sediment column experiments. The modeling results are shown in Figure 31 for the model PCBs. The model successfully reproduced the effect of AC mixing regimes, AC distribution, and AC particle size observed in the experiments. The following characteristics were

demonstrated in the sediment column experiments with different conditions and were clearly shown in the modeling results: i) improved effectiveness of AC amendment for smaller AC particles, which was more evident at the early stages, ii) only slight or no AC benefit for layered-AC columns, indicating a significant effect of AC distribution, iii) no enhancement of effectiveness by re-mixing the sediment and AC 5 days after initial mixing (compare 2 min mix and 2×2 mix columns), and iv) slight enhancement of effectiveness by increased initial mixing time (compare 2 min mix and 30 min mix columns). These results suggest that the PCB mass transfer model was able to capture the key mechanisms of mass transfer that result in variable effectiveness of AC treatment with different AC application scenarios.

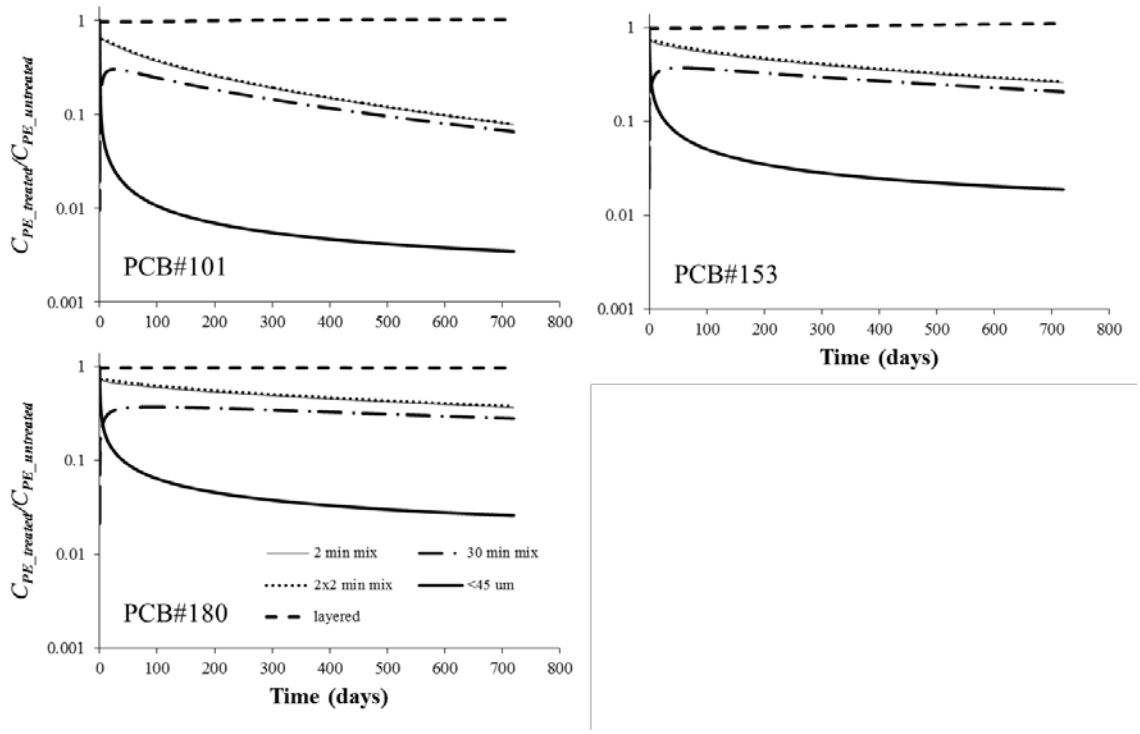


Figure 31. Simulation results for the sediment columns studies with different AC application scenarios under no pore-water movement (AC dose = 4 dry wt%) for the model PCBs in HP sediment.

The comparison between the modeling results for no-flow and flow conditions with 2 min mixing, and 75-150 μm AC showed that the flow effect was not pronounced during the first few months of stagnant AC-sediment contact as shown in the column studies. The model predicted a moderate flow effect after a year or more AC-sediment contact because of the advective mass transfer and/or the greater dispersion in the presence of pore-water flow. This was not observed in the column studies, presumably because of the DOM-facilitated mass transfer for the no-flow conditions. It is also possible that the flow effect was not significant enough to result in identifiable difference in the experiments. With longer periods of AC-sediment contact, the model predicted that the difference between the no-flow and flow conditions became smaller as sufficient time is allowed for the contaminant mass transfer through sediment pores. This can be more evidently seen in the long-term PCB modeling results presented in Section 1.1.

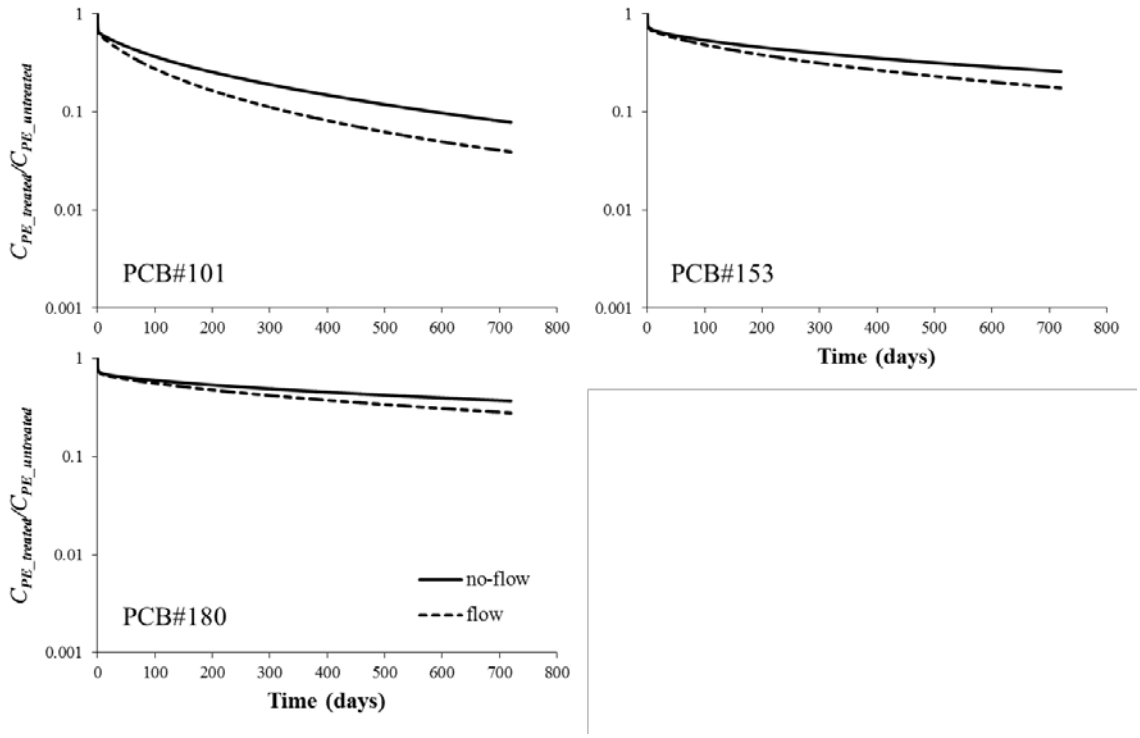


Figure 32. Simulation results for the sediment columns studies with 2 min mixing, 75-150 μm AC (AC dose = 4 dry wt%) under no pore-water movement (no-flow) and 5 cm/d pore-water flow as Darcy's velocity (flow) for the model PCBs in HP sediment.

Overall, the PCB mass transfer model successfully reproduced the experimental results observed in the column studies. The model predicted the effectiveness of AC amendment slightly conservatively, but this may be acceptable regarding the possible uncertainties such as insufficient mixing and seasonal variability in the field. The ability of the model to reproduce the variable effectiveness of AC treatment with different AC application scenarios suggests that the model will be useful for the selection and optimization of the engineering parameters for the treatment (e.g., AC particle size, mixing duration, mode of application, etc.).

1.2.3.2. Application of the modeling results to engineering AC remedy.

In this section, it is discussed how to apply the PCB mass transfer modeling results for engineering AC remedy as a response to the comments at the 2012 In-Progress Review Meeting. The underlying assumption for the discussion is that a cleanup goal is set with respect to contaminant concentration in sediment pore-water. *In-situ* AC amendment effectively reduces the availability of HOCs in sediment, which can be expressed as pore-water concentration, but the sequestration process itself does not reduce the total contaminant sediment concentration. If a cleanup goal is expressed as sediment concentration, methods to correlate the sediment concentrations to pore-water concentrations are needed. The simplest way would be to impose the same target percent reduction in sediment concentration to the precent reduction in pore-water concentration. In this way, the cleanup goal expressed as pore-water concentration for AC amendment ($C_{aq,cleanup}$; g/cm^3) can be calculated as

$$C_{aq,cleanup} = C_{aq,0} \frac{C_{sed,cleanup}}{C_{sed,0}} \quad (8)$$

where $C_{aq,0}$ (g/cm^3) and $C_{sed,0}$ (g/g) are the pore-water and sediment concentration prior to the remedial action, respectively, and $C_{sed,cleanup}$ is the cleanup goal as sediment concentration. If contaminant concentration in biota is of concern, a biological uptake model may be needed to correlate the modeling results (i.e., concentrations in pore-water, sediment, and AC) with the biota concentration.

As shown in this study, the PCB mass transfer model is able to simulate different field application scenarios with variations in AC dose and particle size, AC mixing homogeneity, and AC application modes. At each condition, the model is run to calculate the aqueous concentration in sediment pore-water (C_{aq}, g/cm^3) as a function of time. The aqueous concentration at the end of a remediation project can be compared to the cleanup goal to investigate whether the AC amendment under the simulated scenario is capable of achieving the goal within a targeted time period.

Variable AC doses and particle sizes can be studied to optimize those parameters for field application. Although the effectiveness of treatment is improved with higher AC doses and smaller particle sizes, the ecotoxicological effect by AC may also increase (Jonker, Suijkerbuijk et al. 2009; Kupryianchyk, Reichman et al. 2011). Therefore, AC dose and particle size should be optimized to minimize the potential toxic effect while ensuring the achievement of the cleanup goal. AC dose can be chosen as 1.5 to 2 times the minimum value to achieve the cleanup goal based on the modeling results, because of possible mal-distribution of AC into target sediment layer as observed in our previous ESTCP project. AC particle size may be chosen as the maximum size range that achieves the cleanup goal in a reasonable time based on the modeling results.

The modeling results can be used to screen mixing alternatives and AC application modes. For mixing alternatives, a preliminary mixing study with millimeter-scale AC dose measurements may be needed to characterize AC distribution after the mixing. The model is run for the characteristic AC distribution by each mixing alternative and/or AC application mode. The modeling results are compared to the cleanup goal to exclude the mixing alternatives and/or AC application modes that will not be able to achieve the goal within a targeted time period.

The PCB mass transfer model can be extended and revised to predict the effectiveness of sediment remediation alternatives other than *in-situ* AC amendment. Because the model builds on fundamental scientific knowledge of HOC mass transfer processes, the rationale of the model can be applied to any process involved in controlling the mass transfer processes. For example, the model can be used to evaluate a sand cap alternative by accommodating a clean, sand layer on top of contaminated sediment and calculating the contaminant flux from sediment to overlying water. Remedial options such as thin-layer capping and monitored natural attenuation (MNR) by clean sediment deposition can also be evaluated by the PCB mass transfer model after modifications. To evaluate the effectiveness of thin-layer capping and MNR, the effect of bioturbation by benthic organisms needs to be taken into account because of the major role

bioturbation plays on the mass transfer processes of the two remedial options. Follow-up studies will be needed to modify and validate the PCB mass transfer model for different remedial options and evaluate the effect of bioturbation on HOC mass transfer processes.

2. Evaluate possible adverse effects of sorbent-amendments on local invertebrates

2.1. Nutrient affinity of sorbent.

Some previous studies hypothesized that AC amendment to sediment may cause adverse effects on organisms because the AC may bind organic substrate compounds and hence reduce food availability. The present study showed that the total nitrogen content of AC particles increased by factor 32 after contacting AC with a nitrogen-rich fish food slurry (virgin AC total nitrogen (TN, weight %) = 0.04 ± 0.01; contacted carbon with fish food, TN = 1.29 ± 0.07; fish food, TN = 7.47 ± 0.10). The high affinity for AC to organic matter is supported by a large body of literature assessing sorption of humic substances or dissolved organic carbon, e.g., a study by Summers and Roberts (Summers and Roberts 1988) employing the F400 Carbon used in the present study.

2.2. Sediments.

The sediments used in these suite of tests differ in total organic carbon content (TOC), total nitrogen content (TN) as well as PCB and PAH concentrations (Table 15). Sediments from Holy Island, Blyth Harbor and Blackwater show low pollution levels of polycyclic aromatic hydrocarbons (PAHs; < 2 ppm) and PCBs (< 5 ppm) and can be appropriately used as background reference sediments.

Table 15. Sediment properties.

Sediment ID	**Total PAHs µg/kg ± SD**	**Total PCBs µg/kg ± SD**	**TOC % ± SD**	**TN % ± SD**
Holy Island	435 ± 99	0.27 ± 0.02	0.17 ± 0.06	0.005 ± 0.004
Blyth Harbor	1,777 ± 306	4.49 ± 0.35	1.70 ± 0.42	0.038 ± 0.026
Blackwater	1,876 ± 333	43.42 ± 9.37	2.53 ± 0.06	0.269 ± 0.007
Hunters Point	1,289 ± 404	1,085.71 ± 256.6	1.10 ± 0.2	0.1 ± 0.002
Richmond	17,400 ± 1.000	39.32 ± 1.65	2.8 ± 0.0	0.16 ± 0.01

Within the reference sediments, sediments from Holy Island and Blyth Harbor are sandy and have low TOC and TN, while the Blackwater sediment shows elevated nutrient levels. Hunters Point sediment shows highest PCB pollution (< 1 ppm) and Richmond sediment is polluted by PAHs (> 17 ppm). Hunters Point is more nutrient-limited and the Richmond sediment shows higher TOC and TN levels. These sediments allow comparison of the difference among reference sediments versus polluted sediments as well as the influence of different nutrient concentrations on possible adverse effects of AC amendments.

2.3. Bioassays

2.3.1. Burrowing, survival and weight change.

Organisms started borrowing within minutes for all exposure matrices investigated with no sign of avoiding the AC amendments. Visual inspection confirmed the presence of gut content in approximately 80% of the organisms exposed to sediment, independent of the amendment type. Average survival ranged from 77 to 100% (Figure 33). For the nutrient-limited sediments, i.e., Holy Island and Blyth Harbor, survival tends to be lower when exposed to 20% AC amendments (80 to 83% and 77% to 83%, respectively) than to untreated sediments (97%, both sediments). However, these trends are not statistically significant (ANOVA, $p > 0.05$). No such trend is observed in the Blackwater, Hunters Point or Richmond sediment. Starvation in silica sand for 21 days was not lethal to the organisms (99% survival).

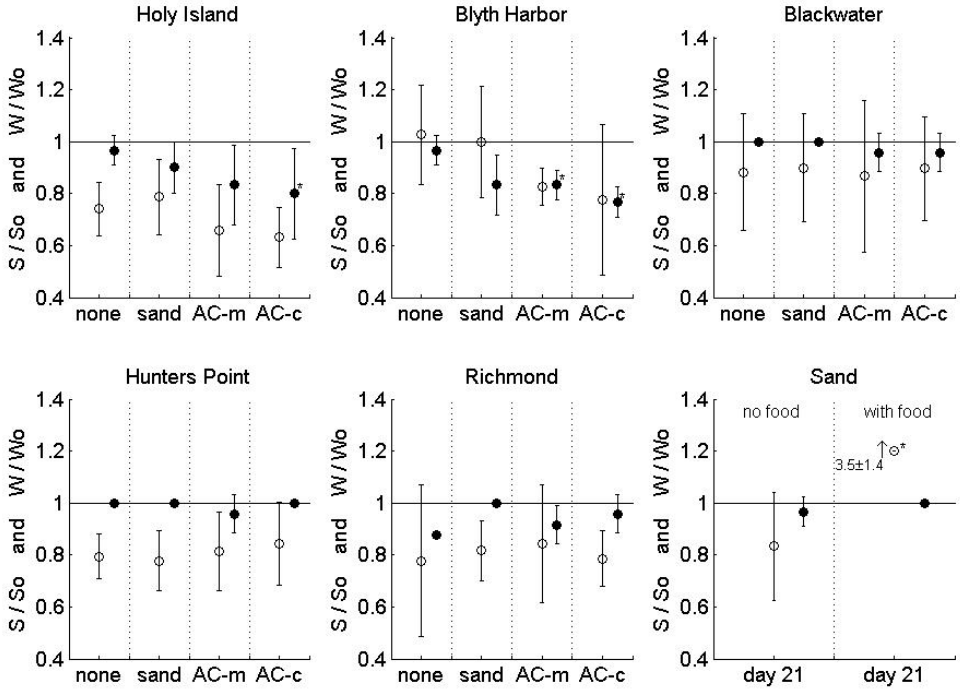


Figure 33. Survival (closed symbols) and weight change (open symbols) after 21 days relative to initial values (t=0) for exposure to five sediments with different treatments (none, 20% sand, 20% AC medium, 20% AC coarse) and sand only. N=12-30. Error bars equal one standard deviation, the horizontal solid lines indicate no change (y=1), asterisk indicate ANOVA with $p < 0.05$.

Data in Figure 33 also show the weight changes of individual worms after 21 day exposure relative to initial weights. Only intact worms that were vital and showed no sign of a clipped tails were used for the weight change analysis. No correlation between the initial worm weights and final weights was observed (ANOVA, $p > 0.05$). Across sediments, weight changes

of organisms were significantly different from each other (ANOVA, $p < 0.0001$). There was no weight change for organisms in untreated Blyth Harbor sediment but exposure to all other untreated sediments resulted in significant weight loss with an average range of -12% to -26%. The weight loss was highest for exposure to untreated Holy Island sediment, which is the sediment with lowest nutritional value. However, despite a higher TOC and TN content of the untreated Blackwater and Richmond sediment, exposure still resulted in significant weight loss (-12% and -23%, respectively).

Identification of significant differences within the sediment treatments is challenged by high biological variability for recorded weight changes. Nevertheless, Holy Island and Blyth Harbor sediments show higher weight loss after exposure to 20% AC amendments relative to organisms from untreated sediment or starvation in sand (for Holy Island: AC-c, Blyth Harbor: AC-m and AC-c; ANOVA; Fisher (LSD) test, $p < 0.05$). On the other hand, no influence of the 20% AC amendment was observed for exposure to Blackwater, Hunters Point or Richmond sediment (ANOVA, $p > 0.05$). No statistical difference was observed among sediment amendments with ingestible, medium sized (AC-m) and non-ingestible, coarse AC (AC-c) (ANOVA, $p > 0.05$). The 20% sand amendments did not affect weight loss (ANOVA, $p > 0.05$). Hence, mechanisms of the effect of 20% AC dose on the deposit feeders are neither dependent on ingestion of the AC particles nor due to dilution of the sediment. The 20% amendment doses are well above remedial treatment levels anticipated for *in-situ* amendments with AC, but may be representative of other *in-situ* treatments (e.g., active capping, localized overdosing). Tests with the 20% AC dose were employed to force possible secondary effects and increase the 'signal-to-noise' ratio of natural variability. The lack of weight gain and weight reduction upon exposure to even untreated sediments indicates that these sediments offer insufficient food supply to the organisms. In these situations, the deposit feeders most likely rely on *in-situ* organic deposits for their food supply rather than from sediment ingestion itself.

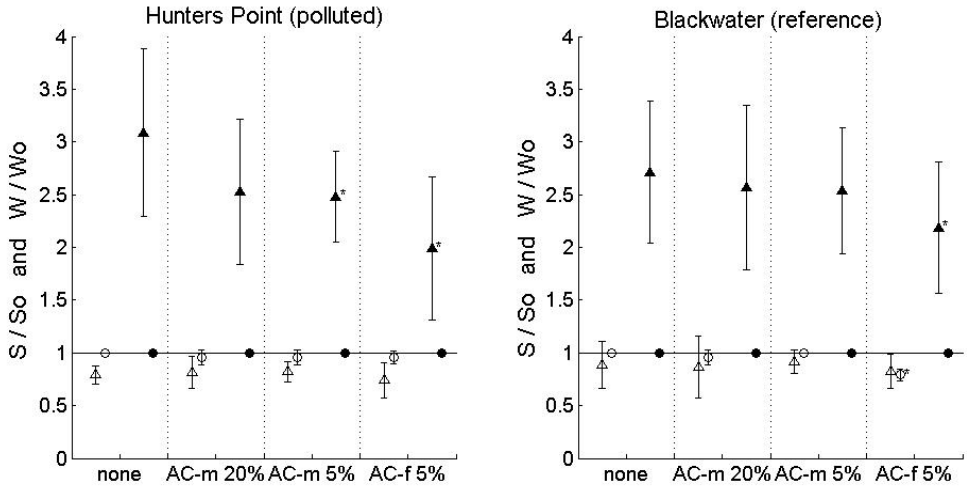


Figure 34. Survival (circles) and weight change (triangles) after 21 days exposure with fish food supply (closed symbols) and without food supply (open symbols) relative to initial values (t=0) to Hunters Point sediment (left) and Blackwater sediment (right) for different treatments (none, 20% AC medium, 5% AC medium, 5% AC fine). N=12-30. Error bars equal one standard

deviation, the horizontal solid lines indicate no change (y=1), asterisk indicate ANOVA with $p < 0.05$.

Additional tests were conducted with Hunters Point (polluted) sediment and the reference sediment from Blackwater to assess influences of finer AC, lower AC dose, and addition of food during exposure. Organisms were exposed to untreated sediments and amendments with 20% AC-m (180-350 µm), 5% AC-m, and 5% AC-f (< 45 µm). Survival and weights after 21 days exposure relative to initial values are shown in Figure 34. The organisms' weights were similar for all exposure tests without feeding, ranging from -9% to -26% weight loss relative to initial weights. On the other hand, significant differences among the treatments were observed when fish food was supplied during exposure. Weight increase was highest for organisms exposed to untreated sediments (Hunters Point: $W/W_0 = 3$; Blackwater sediment: $W/W_0 = 2.7$). Less weight gain was observed for organism exposure to AC amendments (ANOVA, $p < 0.0001$) for all amendments with Hunters Point sediment and amendment with finest AC and Blackwater sediment. Exposure to medium-sized AC resulted in similar weights regardless of the dose of 20% and 5% for Hunters Point ($W/W_0 = 2.5$ and 2.4, respectively) and Blackwater sediment ($W/W_0 = 2.6$ and 2.5, respectively). However, the finest AC at a dose of 5% resulted in the lowest weight gain for both sediments (Hunters Point $W/W_0 = 2.0$, Blackwater $W/W_0 = 2.2$). Organism survival was not affected by the sediment type (polluted versus non-polluted), the AC dose (20% versus 5%), the AC particle size, or the absence or presence of additional fish food with one exception. Survival was slightly lower for exposure to 5% finest AC (AC-f) but only for Blackwater sediment (79% versus 100% of other treatments).

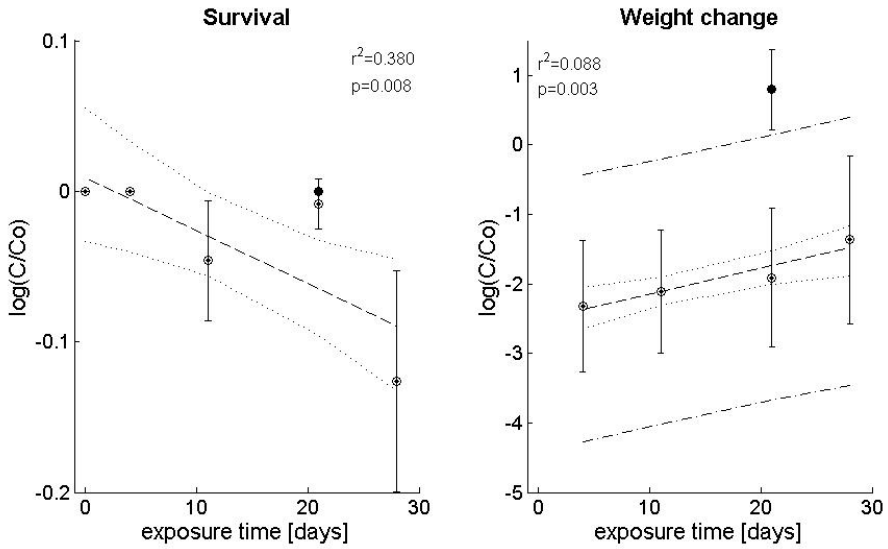


Figure 35. Survival (left) and weight change (right) in percent of individual worms (N=12-30) after exposure to silica sand without feeding (open symbols) and with feeding (closed symbols) over the exposure time of 4 to 28 days. Error bars equal one standard deviation, linear regression (--), 95% confidence intervals of mean (..), 95% confidence interval of observations (:-).

Survival rates and weight change were also assessed during starvation in sand with intermediate sampling (Figure 35). Starvation in sand shows a negative trend of less survival (ANOVA, $p = 0.009$) but weight changes are not highly correlated with the exposure time.

Survival and weight change of organisms that were fed during exposure show higher survival and weight, and can be clearly differentiated from the starving organisms (Figure 35). Overall, the weight loss after exposure to most sediments was similar to weight loss during starvation in sand supporting the poor nutritional quality of the sediments themselves.

2.3.2. Energetic biomarkers.

The energy reserve of protein, lipid and glycogen are presented in Figure 36. The protein contents after exposure to reference sediments and treatments do not show statistical differences relative to each other or the initial concentrations at day 0 (ANOVA, $p > 0.05$). Within each sediment, the lipid content did not respond to the presence of AC (ANOVA, $p > 0.05$). For all sediment exposures, the lipid content was lower than before exposure ('Sand', day 0; ANOVA $p < 0.05$). Interestingly, organisms in untreated Blyth sediment also showed reduced lipid contents, even though no severe weight loss was observed. Organisms exposed to reference sediments show similar reduction in lipid content as organisms in sand (ANOVA $p < 0.05$; Fisher (LSD) test). On the other hand, organisms exposed to Hunters Point and Richmond sediments maintained higher lipid contents than those exposed to sand. The observation of higher lipid content is not supported by higher nutrient content of these two sediments, as Hunters Point is rather nutrient limited relative to Richmond or Blackwater. Similar to the lipid results, organisms showed reduced glycogen content upon exposure to all sediments relative to the initial glycogen content and exposure to sand with food supply (ANOVA $p < 0.05$; Fisher (LSD) test). Final glycogen contents were similarly low as after starvation in sand.

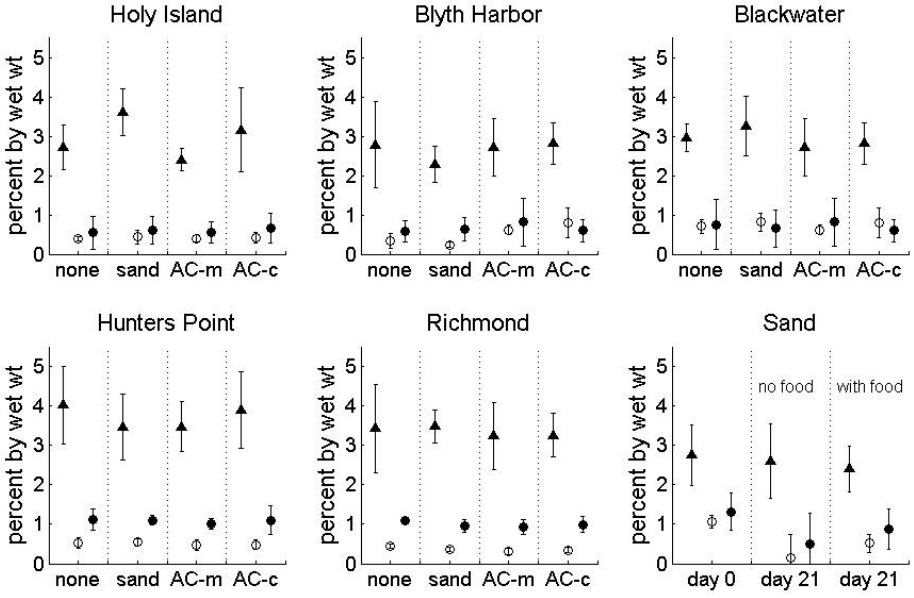


Figure 36. Energy reserves as protein (triangle), lipid (closed circle), and glycogen (open circle) in percent of wet weight of individual organisms after exposure five sediments with different treatments (none, 20% sand, 20% AC medium, 20% AC coarse) and sand only. N = 4-6. Error bars equal one standard deviation.

The energy reserves for organisms following exposure to sand over 4 to 28 days are presented in Figure 37. Starvation in sand shows a significant negative trend with exposure time towards lower energy reserves despite the considerable biological variability (ANOVA, $p < 0.05$). The lipid and glycogen content of organisms, which were exposed to sand but fed during exposure, are significantly higher (Figure 37, closed symbols), while protein contents do not change significantly over time. Glycogen reserves deplete fastest and are most readily available to organisms while lipid and protein reserves are typically exploited at a later stage of starvation. In summary, reduced energy reserves for organisms exposed to sediments is a result of general starvation rather than exposure to AC because results are similar regardless of the sediment treatment.

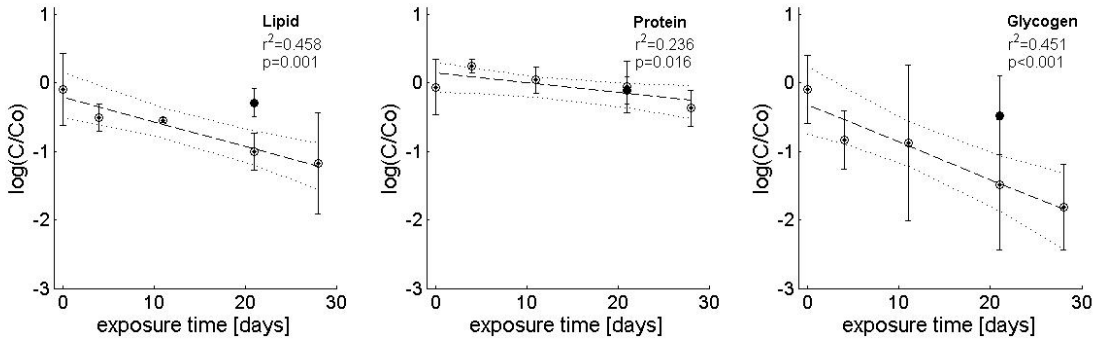


Figure 37. Lipid, protein and glycogen content of individual worms after exposure to silica sand without feeding (open symbols) and with feeding (closed symbols) over the exposure time of 4 to 28 days. N = 3. Error bars equal one standard deviation, linear regression for data without feeding (--), 95% confidence intervals of mean (..).

Data of energy reserve for organisms exposed to finest AC and with additional food supply are presented in Figure 38. In Backwater sediment, organisms that were provided fish food during exposure maintained higher energy reserves than organisms that were not fed (ANOVA $p < 0.05$, Fisher (LSD)). No significant trend was observed among treatments. For Hunters Point sediment, protein and glycogen contents were also higher when food was provided during exposure for all sediment treatments (ANOVA, $p < 0.005$ for protein; $p < 0.0001$ for glycogen; Fisher LSD). Lipid contents were lower for exposure to AC amendments even when food was supplied. Lipid contents were also more affected by finer AC (5% AC-m versus 5% AC-f) and by higher AC dose (5% AC-m versus 20% AC-m; ANOVA, $p < 0.0001$, Fisher LSD).

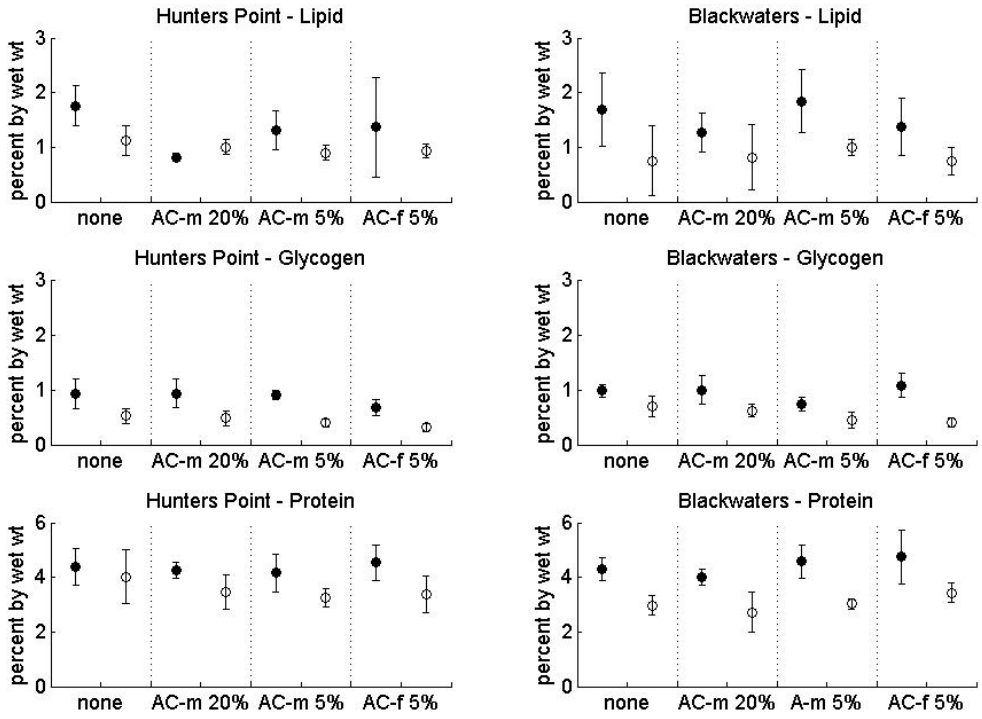


Figure 38. Lipid, protein, and glycogen contents in percent of wet weight of individual organisms after 21 days exposure without food supply (open circles) and with food supply (closed circles) to Hunters Point sediment and Blackwater sediment with different treatments (none, 20% AC medium, 5% AC medium, 5% AC fine). N = 4-6. Error bars equal one standard deviation.

Many of the previous studies for the performance assessment of sorbent amendments as alternative remediation approaches were designed to assess contaminant bioaccumulation rather than an organism's health. Altered dietary conditions for benthic organisms may result in secondary effects due to application of an AC amendment, when not only pollutants but also other organic molecules are strongly sorbing to AC. The present study showed that AC has a high affinity to bind nutrients and the total nitrogen content of AC particles increased by factor 32 after contacting AC with a nitrogen-rich fish food slurry. This is the first study to investigate whether AC particle size affects the organisms externally by sorption processes within the sediment, or internally by ingested AC. Amendments with 20% AC did not affect burrowing, survival or weight of the polychaetes with no difference between ingestible and non-ingestible AC particle sizes. When additional food was supplied during exposure to sediment amendments, organisms grew less in all AC amendments and slightly lower lipid and glycogen contents were observed with higher AC dose and smaller particle size. While some effects on growth and energy reserves were observed, the differences were minimal and AC amendments have little apparent adverse effects on this deposit feeder. The largest effects on the deposit feeders relate to the nutritional quality of the sediment itself, and not the secondary effects of sorbent amendment. Similar assessments of possible secondary effects of AC amendments to benthic invertebrates with different feeding strategies (e.g., filter feeders) and including reproductive endpoints are desired to further ensure that AC amendments are safe remediation alternatives.

VI. Conclusions and Implications for Future Research/Implementation

The research has been successfully completed in regards to the project milestones as summarized below.

1. Mass transfer modeling and long-term effectiveness (Task 6)

1.1. Long-term field monitoring and initial model development of the mass transfer of polychlorinated biphenyls in sediment following pilot-scale *in-situ* amendment with activated carbon (Tasks 6.2 and 6.3).

For the first time, the results from long-term monitoring of field-scale AC amendment are reported and compared with model simulations. Five years after the AC deployment, a clear benefit of AC amendment on the reduction in the PCB uptake was observed for the passive samplers embedded in the AC-amended sediment (73% total PCB pore-water reduction with 3.7 wt % AC dose). The effectiveness of the AC amendment was strongly governed by the local AC-dose. Our numerical model successfully reproduced important experimental observations such as the retarded mass transfer in the field-amended sediment, the effect of PCB homolog, the dose-response relationship, and the temporal trend for the *in-situ* passive sampler uptakes. Furthermore, the discrepancies between the simulations and the actual reduction of pore-water measurements suggest the effect of NOM on field-amended sediment with AC needs to be further investigated. The actual benefit of AC in reducing PCB pore-water concentrations was better than predicted, perhaps because NOM may enhance pore-water diffusion. Comparison of laboratory and modeling results suggest that NOM may assist pore-water diffusion by binding PCBs and slightly diminishing sorption-retarded diffusive transport. Also, our results suggest that NOM itself does not compete with PCB sorption onto AC. Given sufficient time, the estimated partition coefficients between PCBs and AC are similar whether for AC in clean water or AC applied to sediment.

In theory, as long as AC doses are the same, the endpoint concentrations should be the same regardless of AC distribution. In reality, however, our results suggest that the AC distribution will determine the practical benefits seen within a certain monitoring period and the time needed to reach the cleanup goal. Our findings show that the best results in a relatively short time are achieved for small-sized, homogenously distributed AC. Therefore, there are trade-offs between the time to achieve a desired risk reduction, the costs/practical feasibility of homogenous sorbent mixing into the sediment, and the costs of post-treatment monitoring. From an engineering point of view, the homogeneity of the AC distribution will be enhanced by extended mixing time, sequential dosing/mixing, and employing smaller AC particle sizes. The existence of significant advective pore-water movement, mechanical dispersion, or bioturbation can facilitate the adsorption of pollutants by AC under field conditions, although these effects were not obvious at the Hunters Point test site. Considering the long-lasting effects of local dosing variance, possible over-mixing beyond spatial boundaries, or loss during placement operations, it seems necessary to use a safety factor for AC dosing in field applications to assure a minimum desired AC dose throughout the site and to obtain the anticipated benefit from contaminant sequestration. These results emphasize the importance of field trials for the evaluation of AC-based sediment remediation. Furthermore, a robust modeling framework is essential to properly shape the

expectations from the AC amendment considering site-specific conditions. Our model was able to capture the effect by relevant field conditions and the long-term benefit of the field AC amendment.

A manuscript of initial outcomes from Task 6 of this project has been published in *Journal of Contaminant Hydrology* (Cho, Werner et al. 2012).

1.2. PCB mass transfer model enhancement, expansion, calibration, and validation (Tasks 6.3 and 6.4).

The PCB mass transfer model from the initial effort was further modified and optimized for the sediment column study (Tasks 6.4) by considering various field conditions and engineering options. The model performance was enhanced by a remarkable reduction in computational time and a development of a user-friendly I/O interface. The site-specific values of mass transfer parameters for the PCB model compounds were determined by a series of laboratory measurements. The PE-water partitioning coefficients (K_{PE}) were determined for 79 PCB congeners and 21 co-eluting congener groups and the best-fit regression model for the measured K_{PE} values were obtained. These K_{PE} values and the regression model enable the determination of freely dissolved aqueous concentration of any PCB congeners from uptake in PE passive samplers at equilibrium conditions. The results from the sediment column study indicated that the PCB stabilization process was kinetically facilitated by use of smaller AC size, prolonged initial mixing time, and more homogeneous AC-sediment mixing. Especially, the uniformity of AC sorbent distribution in sediment appeared to be critical to obtain a prompt benefit from AC amendment. The PCB mass transfer model was validated by comparing model siumulation results using the experimentally-measured mass transfer parameters and results from the sediment column studies. The model successfully reproduced the effect of AC particle size, AC distribution homogeneity, and mixing regime on the effectiveness of treatment observed in the column studies.

The PCB mass transfer model, as validated with the experimental results under stagnant conditions, can be applied for field application following a guideline provided in this study. With a cleanup goal expressed as pore-water concentration in sediment, the users can run the model to study whether the *in-situ* AC amendment will achieve the cleanup goal within the desired remedial project time period. Further, the users can assess various engineering options like AC doses, AC particle sizes, AC mixing homogeneity, and mode of application in the model to optimize those parameters.

To enhance the reliability of the PCB mass transfer model, it needs to be further validated with actual measurements in larger test systems. Pilot-scale studies or field mesocosm studies provide more realistic systems than the column studies employed in this study. Additional factors that may occur in these field or field-like systems and affect the effectiveness of the treatment should be carefully examined. These factors include contaminant and DOM inflow, sediment deposition, and bioturbation by benthic organisms. If needed, the PCB mass transfer model can be modified to include those factors for the calculation of the effectiveness of AC treatment.

A manuscript that presents the study on the PE-water partitioning coefficients (part of Task 6) is published in *Environmental Science and Technology* (Choi, Cho et al. 2012). Manuscripts that

present the column study and model calibration are being prepared for submission in Environmental Science and Technology.

2. Evaluate possible adverse effects of sorbent-amendment on local invertebrates

Activated carbon (AC) amendments were applied to five sediments and were tested for possible non-toxic, secondary effects on behavior, survival, weight changes and energetic biomarkers of the deposit feeder *Neanthes arenaceodentata*. These deposit feeders proved to be appropriate indicator organisms to test effects of sediment alterations, e.g., pollution exposure or sorbent addition. *N. arenaceodentata* ingest large quantities of sediment and thus reflect the response of organisms with high sediment interaction and exposure. In addition, *N. arenaceodentata* does not discriminate against ingestion of sorbent particles or amended sediment and observed effects should be dominated by a change in (feeding) behavior. Exposure to untreated and AC-amended sediments without additional food supply resulted in similar weight reductions and lower lipid contents. Amendments with 20% AC did not affect burrowing, survival or weight of the polychaetes relative to untreated sediment with no difference between ingestible and non-ingestible AC. Survival was not affected by the sediment type (polluted versus non-polluted), the AC dose (20% versus 5%), the AC particle size, or the presence of additional fish food. In these environments, organisms may rely on organic matter in surface deposits for their diet. When additional food was supplied during exposure, organisms grew significantly and maintained higher lipid glycogen and protein contents. Protein contents were not changed. However, for those experiments, organisms grew less in all AC amendments without an influence of AC dose or particle size. The analysis of energy reserves shows lower lipid and glycogen contents with higher AC dose (i.e., 20%) and smaller particle size. Overall, the absolute effects of AC amendments on growth and energy reserves were minimal.

Many of the previous studies for the performance assessment of sorbent amendments as alternative remediation approaches were designed to assess contaminant bioaccumulation rather than an organism's health. Altered dietary conditions for benthic organisms may cause secondary effects of an AC amendment, when not only pollutants but also other organic molecules are strongly sorbing to AC. This is the first study to investigate whether AC particle size affects the organisms externally by sorption processes within the sediment, or internally by ingested AC. Amendments with 20% AC did not affect burrowing, survival, or weight of the polychaetes with no difference between ingestible and noningestible AC particle sizes. When additional food was supplied during exposure to sediment amendments, organisms grew less in all AC amendments and slightly lower lipid and glycogen contents were observed with higher AC dose and smaller particle size. While no sorption of sediment-associated nitrogen to AC was observed, AC has a high affinity to bind dissolved nitrogen as the total nitrogen content of AC particles increased by a factor of 32 after contacting AC with a nitrogen-rich fish food slurry. These observations suggest that the periodic addition of fish food delivers dissolved nutrients (including nitrogen) to the system, which were more available for sorption to the AC than sediment-associated nitrogen and sorption of soluble fish food nutrients to AC may have suppressed growth.

Overall, the largest effects on the deposit feeders relate to the nutritional quality of the sediment itself, and not the secondary effects of sorbent amendment. For the deposit feeder tested in the presented work, it can be concluded that the AC did not significantly impact the organism's

survival, growth, energy reserves, or behavior. Although various studies are underway to assess possible secondary effects of AC amendments to benthic invertebrates, there is a lack of assessment for reproductive end points. Effects of AC amendments on reproductive end points are especially important to better understand the effects on benthic communities for large-scale field deployments.

Task 7 of this project has been completed and a manuscript of this work has been published in *Environmental Science and Technology* (Janssen, Choi et al. 2012).

VII. Literature Cited

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Appendix A. List of Scientific/Technical Publication

Articles in peer-reviewed journals

Y. Choi, Y.-M. Cho, R.G. Luthy (2013) Polyethylene-water partitioning coefficients for parent- and alkylated-polycyclic aromatic hydrocarbons and polychlorinated biphenyls. *Environ. Sci. Technol. accepted*, doi: 10.1021/es304566v.

E.M.-L. Janssen, Y. Choi, R.G. Luthy (2012) Assessment of non-toxic, secondary effects of sorbent amendment to sediments on the deposit-feeding organism *Neanthes arenaceodentata*. *Environ. Sci. Technol*. 46:4134-4141, doi: 10.1021/es204066g.

Y.-M. Cho, D. Werner, Y. Choi, R.G. Luthy (2012) Long-term monitoring and modeling of the mass transfer of polychlorinated biphenyls in sediment following pilot-scale in-situ amendment with activated carbon. *J. Contam. Hydrol*. 129-130:25-37, doi: 10.1016/j.jconhyd.2012.02.001.

Conference or symposium abstracts

A. Oen, B. Beckingham, Y.-M. Cho, D. Werner, G. Cornelissen, U. Ghosh, R. G. Luthy, The Influence of Field Aging of Activated Carbon in Sediment on PCB Sorption in Field Trials, SETAC Europe 22nd Annual Meeting, Berlin, Germany, 2012.

Y.-M. Cho, Y. Choi, D. Werner, R. G. Luthy, Hunters Point seven-year narrative: In-situ sequestration of HOCs in sediment by activated carbon sorbent amendment. Oral presentation, 243th American Chemical Society (ACS) National Meeting. San Diego, 2012.

R. G. Luthy, Y. Choi, Y. –M. Cho, E.M.-L. Janssen, D. Werner, G. Cornelissen, A. M. P. Oen, Long-term risk reduction from activated carbon treatment of sediment. 2011 Partners in Environmental Technology Technical Symposium & Workshop, Nov 29-Dec 01, 2011, Washington, D.C., USA.

R. G. Luthy, Y. Choi, Y. –M. Cho, E.M.-L. Janssen, D. Werner, G. Cornelissen, A. M. P. Oen, Long-term risk reduction from activated carbon treatment of sediment. 2010 Partners in Environmental Technology Technical Symposium & Workshop, Nov 30-Dec 02, 2010, Washington, D.C., USA.

Text books or book chapters

Y.-M. Cho, D. Werner, E.M.-L. Janssen, R. G. Luthy, In-situ treatment for control of hydrophobic organic contaminants using sorbent amendment, Chapter 11 in Process, Assessment and Remediation of Contaminated Sediment, SERDP ESTCP Remediation Technology, Vol.6, SERDP ESTCP, 2013

Appendix B. Other Supporting Materials

1. User's manual for the PCB mass transfer model

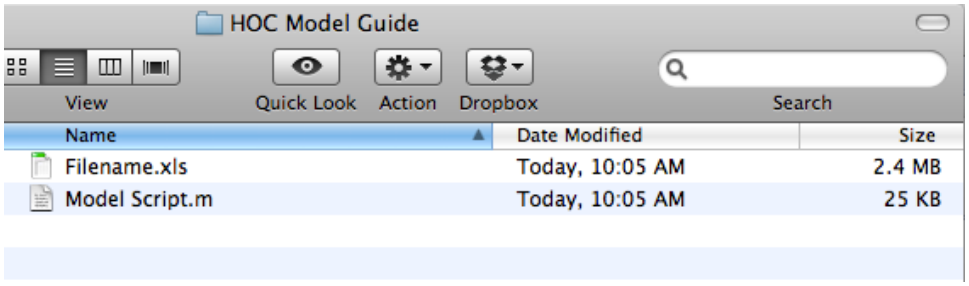
As a response to the comments at the 2012 In-Progress Review Meeting, a user's manual for the PCB mass transfer model is provided.

The model is composed of two parts, a Microsoft Excel® spreadsheet for I/O interface and an Matlab® script for model calculations. The Excel spreadsheet and the Matlab script are submitted as supporting materials for this report. Detailed guidance on the determination of the model input parameters are provided in the Excel spreadsheet. Firstly, the users should enter the model input parameters (i.e., the AC-sediment contact time, model dimension, timestep and grid size, sediment, AC, and passive sampler properties, and the mass transfer parameters for the model compound) into the Excel spreadsheet. The AC-sediment contact time in a stagnant system may be selected as the full remediation project period. The modeling results are collected occasionally from the calculation loop. For example, for the default case provided in the spreadsheet (i.e., data collection for every 100 time steps with a time step size of 100 seconds for stagnant contact period), the data are saved every 10,000 seconds of simulation period. The model dimension is chosen to cover the full depth of sediment layer for AC amendment (typically 15-30 cm) while minimizing the width and length (down to 2 mm) assuming that the sediment properties and AC distribution is horizontally invariable. Default values provided in the spreadsheet can be used for timestep, grid size, and passive sampler properties (for PE only). If site-specific values are not available, users can also use default values provided for sediment and AC properties.

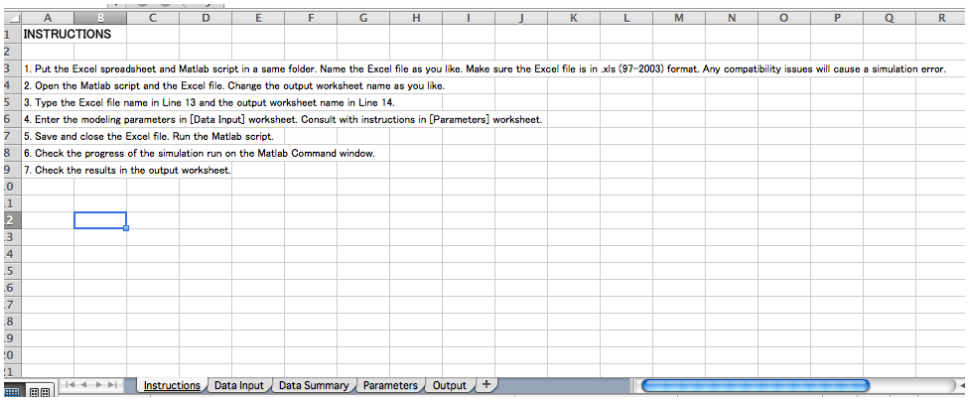
The users should determine the sediment mass transfer parameters for the model contaminant by a series of experiments conducted in the current study (described in details in section IV-1.2) or by a literature survey. Except for the parameters involved in passive samplers (i.e., passive sampler-water partitioning coefficient (K_{PS}) and the mass transfer coefficient for passive sampler (k_{PS})), the sediment mass transfer parameters are likely to vary by site conditions. Therefore, the experimentally determined parameters are expected to generate more accurate modeling results than the literature values. In particular, the sediment desorption parameters should be determined by a sediment desorption test because the values are almost completely site-specific.

After all the model input parameters are determined and entered in the Excel spreadsheet, the users are guided by the instructions shown in the Excel spreadsheet to open the Matlab script, enter the name of the Excel I/O file, and run the script for model calculation. The Matlab script takes input parameters from the Excel spreadsheet and exports the modeling results back to the spreadsheet. The following data are reported at each time step for data collection: aqueous concentration, passive sampler concentration, and mass fractions in AC, sediment fast- and slow-releasing fractions, passive sampler, and water. The output results are shown numerically as well as graphically in the spreadsheet for easy data examination and export.

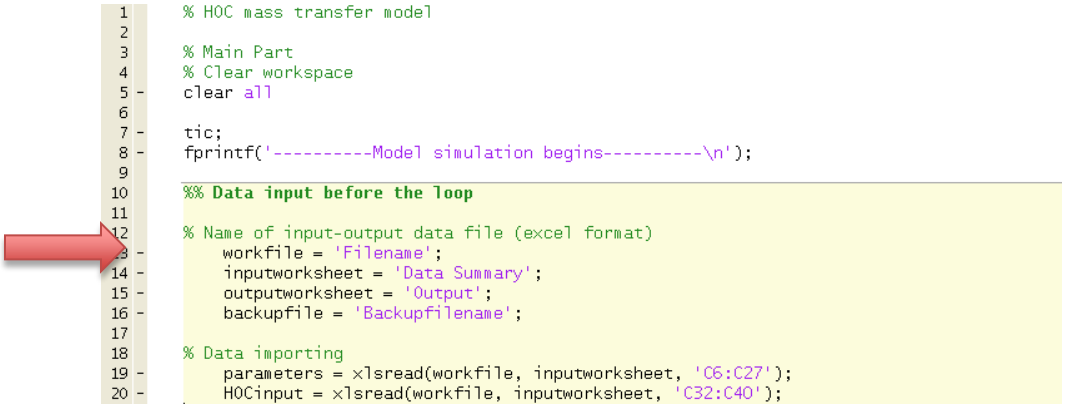
Step 1. I/O interface file (Filename) and model scrip (Model Script.m) placed in a same folder. Name the I/O file accordingly.



Step 2. Open the I/O file (Filename.xls). Five tabs shown (Introduction, Data Input, Data Summary, Parameters, Output).



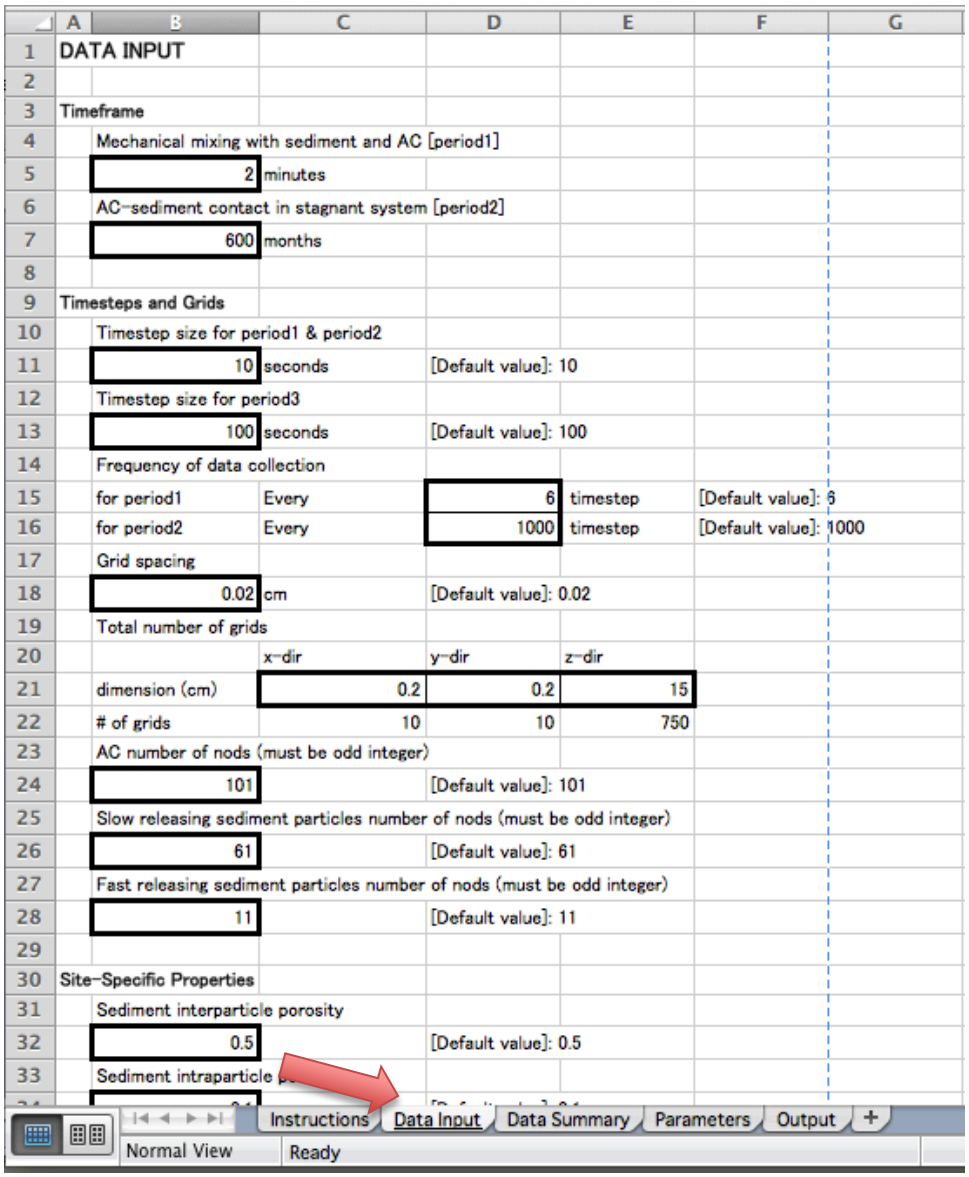
Step 3. Open the script file using Matlab®. Check I/O data file/workspreadsheet names (lines 12-16).



```
1    % HOC mass transfer model
2
3    % Main Part
4    % Clear workspace
5 -  clear all
6
7 -  tic;
8 -  fprintf('----------Model simulation begins----------\n');
9
10   %% Data input before the loop
11
12   % Name of input-output data file (excel format)
13 -     workfile = 'Filename';
14 -     inputworksheet = 'Data Summary';
15 -     outputworksheet = 'Output';
16 -     backupfile = 'Backupfilename';
17
18   % Data importing
19 -     parameters = xlsread(workfile, inputworksheet, 'C6:C27');
20 -     HOCinput = xlsread(workfile, inputworksheet, 'C32:C40');
```

workfile: I/O spreadsheet file, ‘Filename’
inputworksheet: worksheet with model parameters, ‘Data Summary’
outputworksheet: worksheet for model results, ‘Output’
backupfile: file for backup data, ‘Backupfilename’

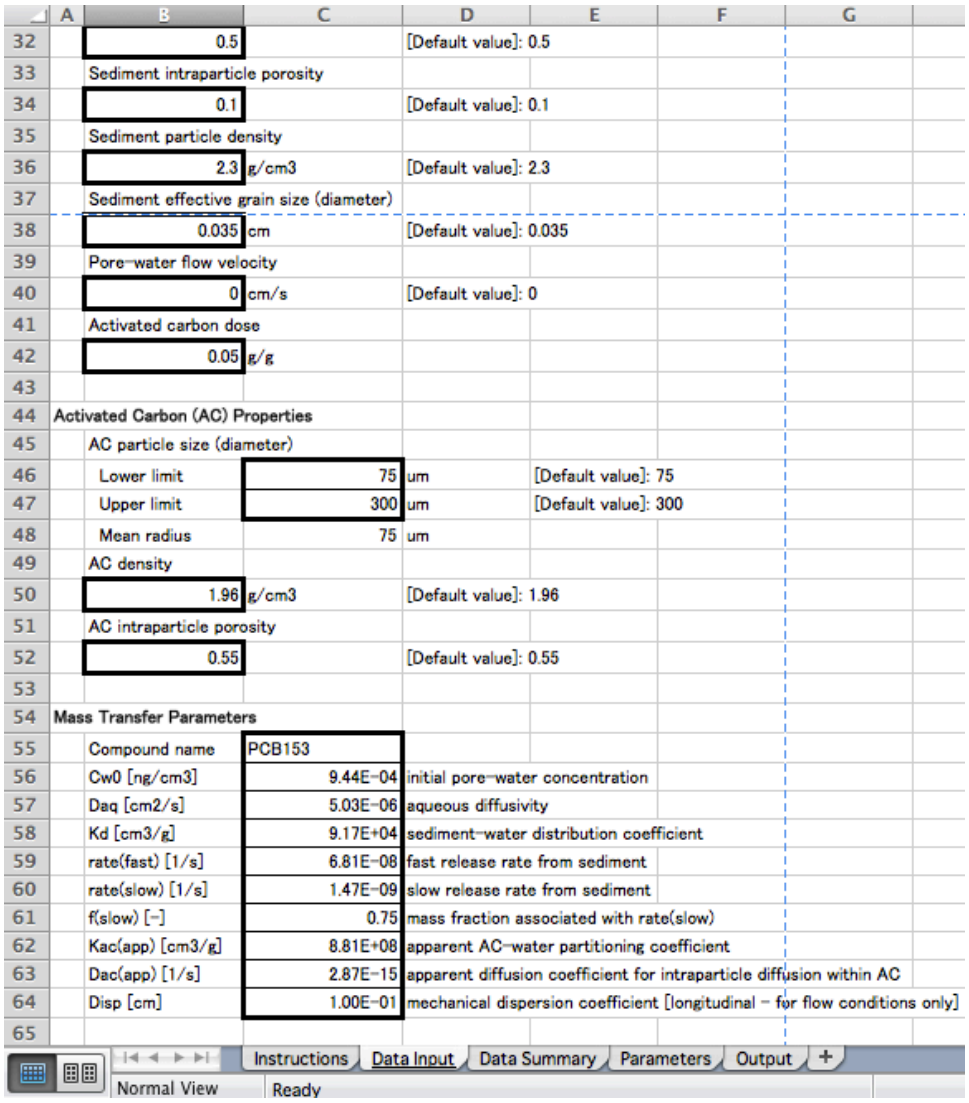
Step 4. Enter the model parameters into ‘Data Input’ worksheet. Refer ‘Parameter’ worksheet for guidance. Be sure to insert all parameters.



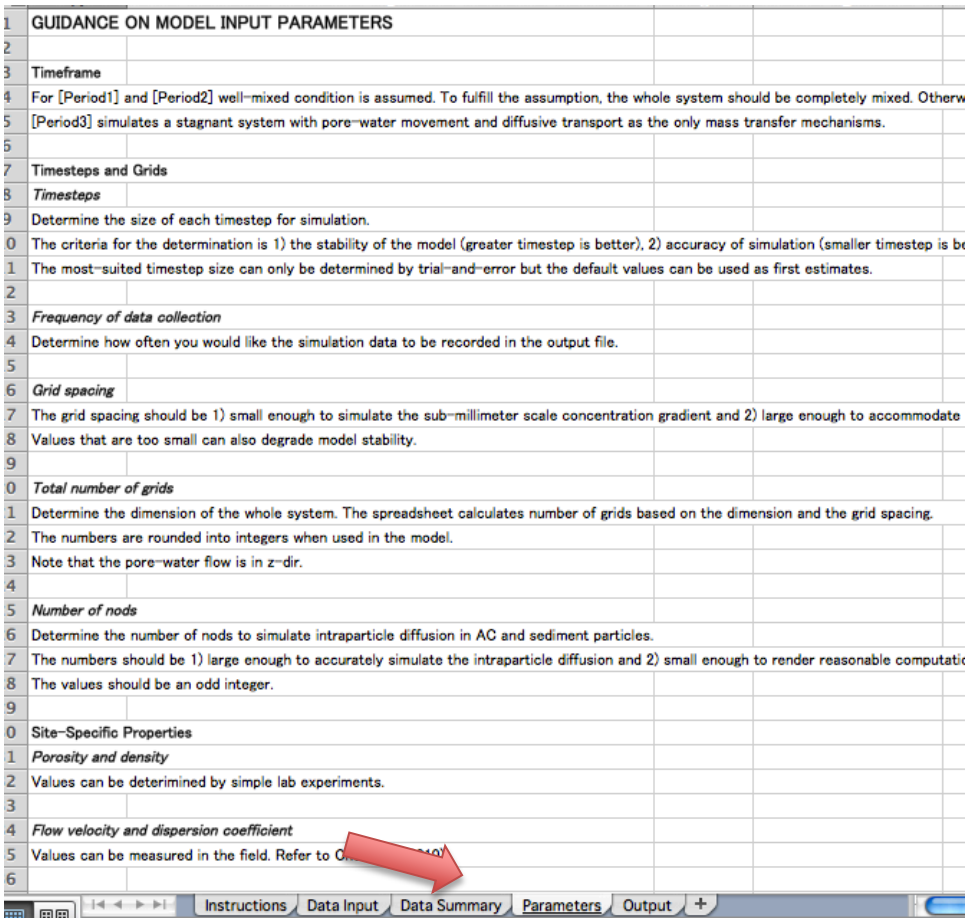
	A	B	C	D	E	F	G
1	DATA INPUT						
2							
3	Timeframe						
4		Mechanical mixing with sediment and AC [period1]					
5		2	minutes				
6		AC-sediment contact in stagnant system [period2]					
7		600	months				
8							
9	Timesteps and Grids						
10		Timestep size for period1 & period2					
11		10	seconds	[Default value]: 10			
12		Timestep size for period3					
13		100	seconds	[Default value]: 100			
14		Frequency of data collection					
15		for period1	Every	6	timestep	[Default value]: 6	
16		for period2	Every	1000	timestep	[Default value]: 1000	
17		Grid spacing					
18		0.02	cm	[Default value]: 0.02			
19		Total number of grids					
20			x-dir	y-dir	z-dir		
21		dimension (cm)	0.2	0.2	15		
22		# of grids	10	10	750		
23		AC number of nods (must be odd integer)					
24		101		[Default value]: 101			
25		Slow releasing sediment particles number of nods (must be odd integer)					
26		61		[Default value]: 61			
27		Fast releasing sediment particles number of nods (must be odd integer)					
28		11		[Default value]: 11			
29							
30	Site-Specific Properties						
31		Sediment interparticle porosity					
32		0.5		[Default value]: 0.5			
33		Sediment intraparticle p					

Instructions | Data Input | Data Summary | Parameters | Output | +

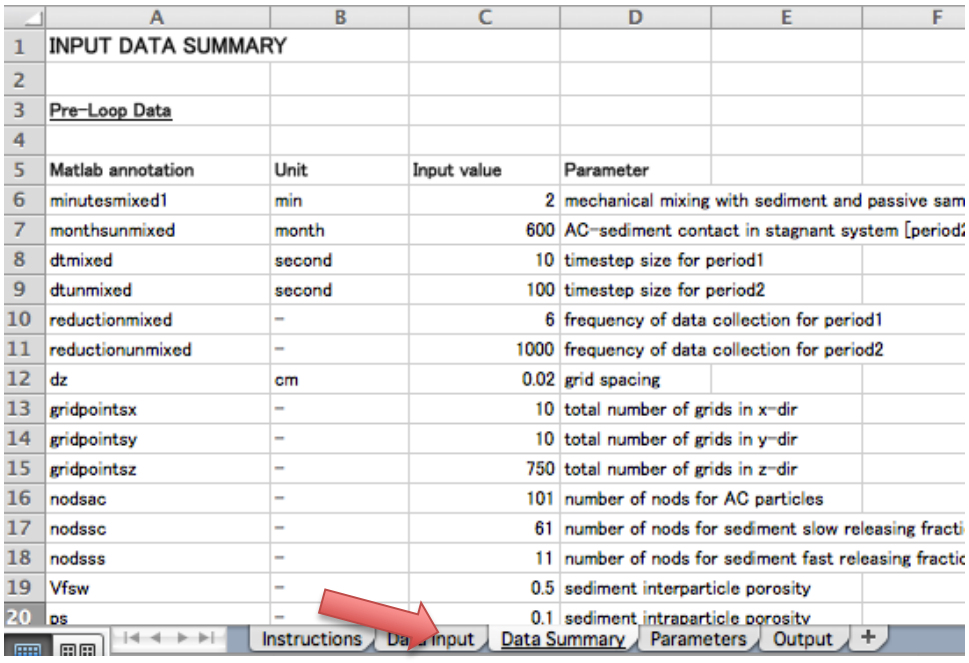
Normal View | Ready



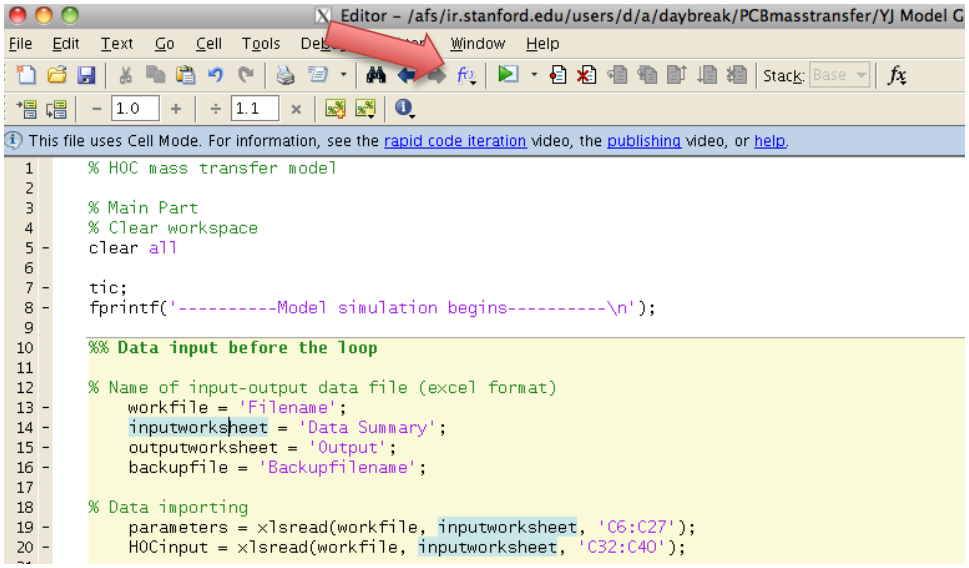
	A	B	C	D	E	F	G
32		0.5		[Default value]: 0.5			
33		Sediment intraparticle porosity					
34		0.1		[Default value]: 0.1			
35		Sediment particle density					
36		2.3	g/cm3	[Default value]: 2.3			
37		Sediment effective grain size (diameter)					
38		0.035	cm	[Default value]: 0.035			
39		Pore-water flow velocity					
40		0	cm/s	[Default value]: 0			
41		Activated carbon dose					
42		0.05	g/g				
43							
44	Activated Carbon (AC) Properties						
45		AC particle size (diameter)					
46		Lower limit	75	um	[Default value]: 75		
47		Upper limit	300	um	[Default value]: 300		
48		Mean radius	75	um			
49		AC density					
50		1.96	g/cm3	[Default value]: 1.96			
51		AC intraparticle porosity					
52		0.55		[Default value]: 0.55			
53							
54	Mass Transfer Parameters						
55		Compound name	PCB153				
56		Cw0 [ng/cm3]	9.44E-04	initial pore-water concentration			
57		Daq [cm2/s]	5.03E-06	aqueous diffusivity			
58		Kd [cm3/g]	9.17E+04	sediment-water distribution coefficient			
59		rate(fast) [1/s]	6.81E-08	fast release rate from sediment			
60		rate(slow) [1/s]	1.47E-09	slow release rate from sediment			
61		f(slow) [-]	0.75	mass fraction associated with rate(slow)			
62		Kac(app) [cm3/g]	8.81E+08	apparent AC-water partitioning coefficient			
63		Dac(app) [1/s]	2.87E-15	apparent diffusion coefficient for intraparticle diffusion within AC			
64		Disp [cm]	1.00E-01	mechanical dispersion coefficient [longitudinal - for flow conditions only]			
65							



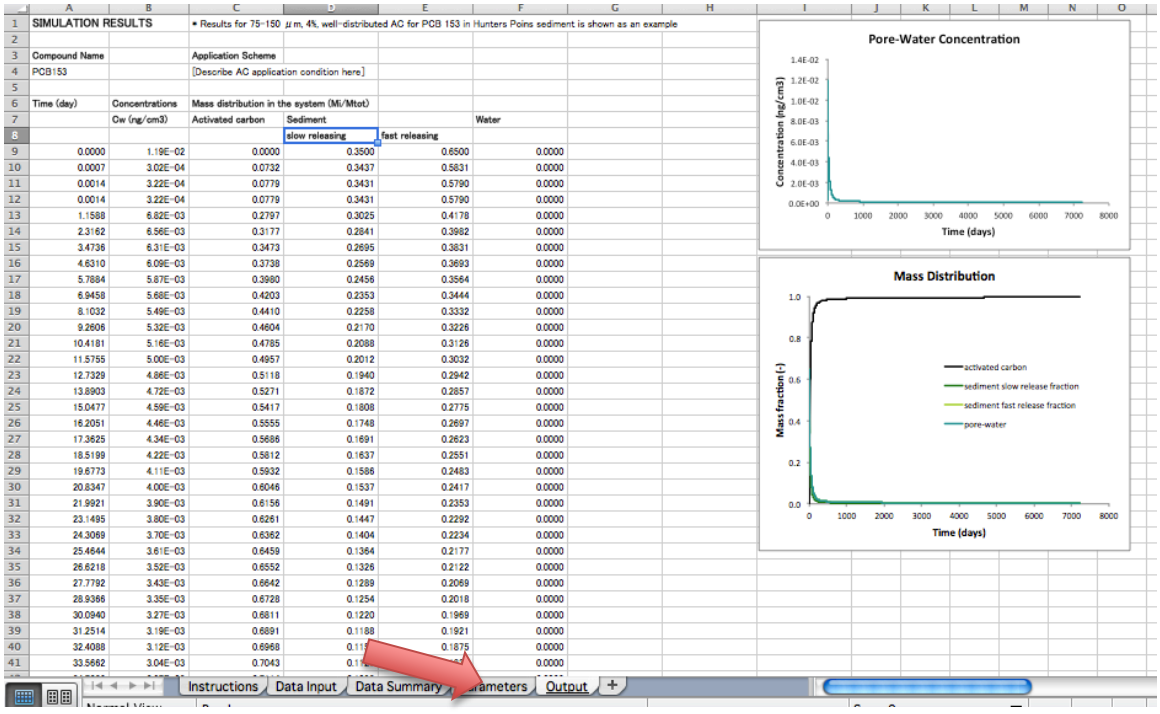
Step 5. Check 'Data Summary' worksheet for actual input parameters.



Step 6. Save the I/O file and run the Matlab® script.



Step 7. Check the result in 'Output' spreadsheet.



2. PCB mass transfer model code script and I/O interface file

Appendix C. Numerical Data for Figures

As supporting information, numerical data used to construct Figures 17, 18, 24-30, and 33-37 are provided in this section.

Table C1. Numerical data for Figure 17: measured and modeled 28-day PE uptakes (ng/kg PE) five years after AC-amendment of PCB 101, PCB 153, and PCB 180.

(a) PCB#101

AC dose (%)	**Measured PE uptakes (ng/kg PE)**	**Measurement ($C_{PE\_treated}/C_{PE\_untreated}$)**	**Simulation results ($C_{PE\_treated}/C_{PE\_untreated}$)**
0 (Untreated)	75	N/A	N/A
1.7	40	0.53	0.18
2.1	37	0.49	0.11
2.5	29	0.39	0.08
2.7	23	0.31	0.10
3.1	17	0.23	0.10
3.7	10	0.14	0.06

(b) PCB#153

AC dose (%)	**Measured PE uptakes (ng/kg PE)**	**Measurement ($C_{PE\_treated}/C_{PE\_untreated}$)**	**Simulation results ($C_{PE\_treated}/C_{PE\_untreated}$)**
0 (Untreated)	123	N/A	N/A
1.7	76	0.61	0.89
2.1	81	0.66	0.70
2.5	60	0.48	0.58
2.7	55	0.44	0.65
3.1	48	0.39	0.41
3.7	34	0.28	0.40

(c) PCB#180

AC dose (%)	**Measured PE uptakes (ng/kg PE)**	**Measurement ($C_{PE\_treated}/C_{PE\_untreated}$)**	**Simulation results ($C_{PE\_treated}/C_{PE\_untreated}$)**
0 (Untreated)	57	N/A	N/A
1.7	39	0.68	0.79
2.1	46	0.81	0.74
2.5	31	0.55	0.70
2.7	32	0.57	0.66
3.1	31	0.55	0.64
3.7	25	0.45	0.71

Table C2. Numerical data for Figure 18: measured and modeled 28-day SPMD uptakes (n=3-5 for measurements) and 14-day aqueous equilibrium PCB concentrations (n=3-5 for measurements).

(a) PCB#101

SPMD Uptakes (ng/SPMD)							
AC-sediment contact time (days) & AC dose		1	2	3	4	5	Average± Stdev
26 (4.4±1.7)	AC-treated	6.40	6.02	8.03	8.88	10.4	7.95±1.80
	Control	12.2	11.0	14.6	12.5	10.9	12.2±1.5
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.65±0.17
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.71
210 (3.2±2.8)	AC-treated	6.37	11.3	10.8	-	-	9.50±2.72
	Control	25.9	26.5	25.8	-	-	26.1±0.4
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.36±0.10
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.41
1788 (2.4±0.4)	AC-treated	9.42	7.69	10.2	-	-	9.10±1.23
	Control	17.3	17.7	19.2	-	-	18.0±1.0
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.50±0.29
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.13
Aqueous Concentration (ng/L)							
AC-sediment contact time (days) & AC dose (%)		1	2	3	4	5	Average± Stdev
169 (3.2±0.7)	AC-treated	0.08	0.08	0.08	0.08	0.08	0.08±0.00
	Control	0.96	0.72	0.72	1.14	1.03	0.91±0.19
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.088±0.018
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.0696
538 (2.1±0.5)	AC-treated	0.08	0.13	0.08	0.08	0.08	0.09±0.02
	Control	1.03	1.06	0.95	0.89	1.22	1.03 ±0.12
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.087±0.024
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.0795
1304 (3.3±1.3)	AC-treated	0.46	0.08	0.30	-	-	0.28±0.19
	Control	1.33	1.24	2.59	-	-	1.72±0.75
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.163±0.132
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.0347
1816 (3.0±1.2)	AC-treated	0.15	0.22	0.16	-	-	0.18±0.04
	Control	0.61	0.91	0.76	-	-	0.76±0.15
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.236±0.069
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.0345

(b) PCB#153

SPMD Uptakes (ng/SPMD)							
AC-sediment contact time (days) & AC dose		1	2	3	4	5	Average± Stdev
26 (4.4±1.7)	AC-treated	12.8	12.0	15.2	17.3	17.1	14.9±2.4
	Control	17.0	16.1	19.8	18.0	16.6	17.5±1.5
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.85±0.16
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.84
210 (3.2±2.8)	AC-treated	12.6	18.6	21.5	-	-	17.6±4.5
	Control	32.9	33.9	32.5	-	-	33.1±0.7
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.53±0.14
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.83
1788 (2.4±0.4)	AC-treated	17.0	14.9	17.4	-	-	16.4±1.4
	Control	25.7	27.8	31.4	-	-	28.3±2.9
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.58±0.08
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.59
Aqueous Concentration (ng/L)							
AC-sediment contact time (days) & AC dose (%)		1	2	3	4	5	Average± Stdev
169 (3.2±0.7)	AC-treated	0.08	0.08	0.08	0.08	0.08	0.08±0.00
	Control	0.64	0.77	0.75	1.26	1.05	0.82±0.30
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.098±0.036
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.263
538 (2.1±0.5)	AC-treated	0.08	0.61	0.19	0.10	0.13	0.22±0.22
	Control	1.50	1.72	1.66	1.53	2.23	1.73±0.30
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.129±0.131
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.326
1304 (3.3±1.3)	AC-treated	0.66	0.23	0.49	-	-	0.46±0.22
	Control	1.71	1.81	2.98	-	-	2.17±0.70
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.212±0.121
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.174
1816 (3.0±1.2)	AC-treated	0.40	0.51	0.09	-	-	0.33±0.22
	Control	0.72	0.99	0.80	-	-	0.84±0.14
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.398±0.267
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.179

(c) PCB#180

SPMD Uptakes (ng/SPMD)							
AC-sediment contact time (days) & AC dose		1	2	3	4	5	Average± Stdev
26 (4.4±1.7)	AC-treated	12.3	12.1	14.1	14.5	14.0	13.4±1.1
	Control	12.3	12.2	13.9	13.0	11.9	12.7±0.8
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						1.06±0.11
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.87
210 (3.2±2.8)	AC-treated	14.2	16.3	18.0	-	-	16.2±1.9
	Control	21.2	21.7	20.0	-	-	21.0±0.9
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.77±0.10
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.85
1788 (2.4±0.4)	AC-treated	8.68	7.56	8.22	-	-	8.15±0.56
	Control	10.8	12.0	14.1	-	-	12.3±1.7
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.66±0.10
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.70
Aqueous Concentration (ng/L)							
AC-sediment contact time (days) & AC dose (%)		1	2	3	4	5	Average± Stdev
169 (3.2±0.7)	AC-treated	0.04	0.04	0.04	0.21	0.04	0.07±0.08
	Control	0.13	0.16	0.10	0.65	0.51	0.31±0.25
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.240±0.316
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.380
538 (2.1±0.5)	AC-treated	0.04	1.05	0.44	0.36	0.33	0.44±0.37
	Control	1.21	1.56	1.63	1.47	2.41	1.66±0.45
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.268±0.236
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.456
1304 (3.3±1.3)	AC-treated	0.29	0.04	0.33	-	-	0.22±0.16
	Control	0.61	0.65	0.76	-	-	0.67±0.08
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.324±0.234
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.281
1816 (3.0±1.2)	AC-treated	0.10	0.17	0.04	-	-	0.10±0.07
	Control	0.25	0.21	0.30	-	-	0.26±0.06
	$\mathbf{C_{treated}/C_{control\ (Measured)}}$						0.404±0.275
	$\mathbf{C_{treated}/C_{control\ (Simulated)}}$						0.286

Table C3. Numerical data for Figure 24: concentrations of PCBs in pre-loaded PE samplers and sediment collected from Hunters Point Shipyard. Data are shown as average ± standard deviation of triplicate samples.

Homolog group	**Concentration in sediment (µg/g)**	**Concentration in PE (µg/g)**
mono-	ND[1]	ND
di-	$1.86\times10^{-4}\pm1.67\times10^{-4}$	$2.23\times10^{-3}\pm1.57\times10^{-4}$
tri-	$1.17\times10^{-3}\pm9.50\times10^{-4}$	$4.14\times10^{-2}\pm3.58\times10^{-3}$
tetra-	$3.27\times10^{-2}\pm3.16\times10^{-2}$	$9.49\times10^{-1}\pm5.86\times10^{-2}$
penta-	$1.25\times10^{-1}\pm1.31\times10^{-2}$	$7.78\pm6.77\times10^{-1}$
hexa-	$3.55\times10^{-1}\pm7.90\times10^{-2}$	23.0±1.54
hepta-	$3.99\times10^{-1}\pm1.12\times10^{-1}$	19.8±3.31
octa-	$1.62\times10^{-1}\pm7.46\times10^{-2}$	$4.47\pm7.54\times10^{-1}$
nona-	$9.97\times10^{-3}\pm6.31\times10^{-3}$	$8.63\times10^{-2}\pm6.09\times10^{-2}$
deca-	$1.08\times10^{-3}\pm4.70\times10^{-4}$	$6.18\times10^{-3}\pm3.09\times10^{-3}$
Total PCBs	**1.09±0.26**	**56.1±4.89**

[1]ND: Not detected.

Table C4. Numerical data for Figure 25: experimental data and simulation results with K_{AC_clean} values expressed as absolute amount of 28-day PE uptake (ng/g) for the AC fouling study (n=3 for experimental results, average ± standard deviation).

(a) PCB#101

AC-sediment contact time	Experimental data from AC fouling study (ng/g)			Simulation results using K_{AC_clean} values (ng/g)		
	<45 µm AC	75-150 µm AC	control	<45 µm AC	75-150 µm AC	control
1.5 months	0.755±0.044	4.25±0.60	1090±130	1.17	5.09	586
6 months	0.514±0.066	0.691±0.186	280±42	0.972	3.92	586
12 months	0.514±0.141	1.72±0.02	292±26	0.909	3.43	586
18 months	0.436±0.139	1.39±0.30	254±36	0.884	3.15	586
24 months	0.330±0.054	0.472±0.026	241±20	0.872	2.96	586
30 months	0.229±0.053	0.688±0.175	222±11	0.866	2.81	586

(b) PCB#153

AC-sediment contact time	Experimental data from AC fouling study (ng/g)			Simulation results using K_{AC_clean} values (ng/g)		
	<45 µm AC	75-150 µm AC	control	<45 µm AC	75-150 µm AC	control
1.5 months	3.95±0.72	23.0±0.6	1910±1490	12.6	52.1	1730
6 months	1.03±0.08	1.99±0.53	434±67	10.7	39.9	1730
12 months	1.72±0.19	10.6±2.5	1000±150	10.2	34.8	1730
18 months	1.54±0.26	10.3±3.2	1020±200	10.1	32.0	1730
24 months	1.03±0.44	3.03±1.18	788±170	10.2	29.9	1730
30 months	0.818±0.424	1.85±0.85	736±65	10.3	28.3	1730

(c) PCB#180

AC-sediment contact time	Experimental data from AC fouling study (ng/g)			Simulation results using K_{AC_clean} values (ng/g)		
	<45 µm AC	75-150 µm AC	control	<45 µm AC	75-150 µm AC	control
1.5 months	6.69±1.22	41.7±2.1	1950±273	19.3	79.8	2380
6 months	1.61±0.21	3.01±0.76	260±36	16.3	61.1	2380
12 months	2.85±0.23	16.8±6.4	917±240	15.7	53.6	2380
18 months	2.47±0.13	15.5±4.8	1120±250	15.6	49.5	2380
24 months	1.72±0.87	6.88±3.50	848±280	15.7	46.7	2380
30 months	0.925±0.446	2.55±1.31	676±177	15.9	44.4	2380

Table C4. Numerical data for Figure 25: experimental data and simulation results with K_{AC_clean} values expressed as relative 28-day PE uptake compared to no-AC controls ($C_{PE\_treated}/C_{PE\_untreated}$) for the AC fouling study (n=3 for experimental results, average ± standard deviation).

(a) PCB#101

AC-sediment contact time	Experimental data from AC fouling study ($C_{PE\_treated}/C_{PE\_untreated}$)		Simulation results using K_{AC_clean} values ($C_{PE\_treated}/C_{PE\_untreated}$)	
	<45 µm AC	75-150 µm AC	<45 µm AC	75-150 µm AC
1.5 months	0.0007±0.0001	0.0039±0.0007	0.0020	0.0087
6 months	0.0018±0.0004	0.0018±0.0004	0.0017	0.0067
12 months	0.0018±0.0005	0.0059±0.0005	0.0016	0.0059
18 months	0.0017±0.0006	0.0055±0.0014	0.0015	0.0054
24 months	0.0014±0.0003	0.0020±0.0002	0.0015	0.0051
30 months	0.0010±0.0002	0.0031±0.0008	0.0015	0.0048

(b) PCB#153

AC-sediment contact time	Experimental data from AC fouling study ($C_{PE\_treated}/C_{PE\_untreated}$)		Simulation results using K_{AC_clean} values ($C_{PE\_treated}/C_{PE\_untreated}$)	
	<45 µm AC	75-150 µm AC	<45 µm AC	75-150 µm AC
1.5 months	0.0021±0.0016	0.0120±0.0094	0.0073	0.0301
6 months	0.0024±0.0004	0.0046±0.0014	0.0061	0.0230
12 months	0.0017±0.0003	0.0106±0.0030	0.0059	0.0201
18 months	0.0015±0.0004	0.0100±0.0037	0.0058	0.0185
24 months	0.0013±0.0006	0.0038±0.0017	0.0059	0.0173
30 months	0.0011±0.0006	0.0025±0.0012	0.0059	0.0163

(c) PCB#180

AC-sediment contact time	Experimental data from AC fouling study ($C_{PE\_treated}/C_{PE\_untreated}$)		Simulation results using K_{AC_clean} values ($C_{PE\_treated}/C_{PE\_untreated}$)	
	<45 µm AC	75-150 µm AC	<45 µm AC	75-150 µm AC
1.5 months	0.0034±0.0008	0.0214±0.0032	0.0081	0.0335
6 months	0.0062±0.0012	0.0116±0.0033	0.0068	0.0256
12 months	0.0031±0.0009	0.0183±0.0085	0.0066	0.0225
18 months	0.0022±0.0005	0.0138±0.0052	0.0066	0.0208
24 months	0.0020±0.0012	0.0081±0.0049	0.0066	0.0196
30 months	0.0014±0.0008	0.0038±0.0022	0.0067	0.0186

Table C5. Numerical data for Figure 26: results of no-flow column studies for total PCBs. Data are expressed as absolute total PCB uptake in PE (ng/g) with relative values compared to no-AC controls (%) in parentheses. Data are reported as average ± data range for duplicates.

AC application scenario	**1 month contact**	**3 months contact**	**24 months contact**
control (no AC)	2730±130 ng/g (100.0±4.8%)	3900±110 ng/g (100.0±2.9%)	7990±350 ng/g (100.0±4.4%)
2 min mixing, 75-150 μm AC	807±33 ng/g (29.6±1.2%)	844±270 ng/g (21.7±6.9%)	585±140 ng/g (7.3±1.7%)
30 min mixing, 75-150 μm AC	449±1 ng/g (16.5±0.0%)	587±59 ng/g (15.1±1.5%)	234±72 ng/g (2.9±0.9%)
2×2 min mixing, 75-150 μm AC	803±76 ng/g (29.4±2.8%)	852±52 ng/g (21.9±1.3%)	380±72 ng/g (4.8±0.9%)
2 min mixing, <45 μm AC	390±64 ng/g (14.3±2.4%)	348±10 ng/g (8.9±0.3%)	239±190 ng/g (3.0±2.4%)
layered AC	2960±0 ng/g (108.5±0.1%)	4010±20 ng/g (102.9±0.5%)	5840±320 ng/g (73.0±4.0%)

Table C6. Numerical data for Figure 27: results of no-flow column studies with 2 min mixing and 75-150 μm, and no-AC control for PCB homolog groups. Data are expressed as absolute PCB uptake in PE (ng/g) with relative values compared to no-AC controls (%) in parentheses. Data are reported as average ± data range for duplicates.

PCB homolog group	**1 month contact**		**3 months contact**		**24 months contact**	
	2 min mixing, 75-150 μm AC	**control (no AC)**	**2 min mixing, 75-150 μm AC**	**control (no AC)**	**2 min mixing, 75-150 μm AC**	**control (no AC)**
tetra-	4.90±1.77 ng/g (3.4±1.2%)	142±36 ng/g (100.0±25.4%)	3.48±0.10 ng/g (3.4±0.1%)	102±1 ng/g (100.0±0.8%)	5.24±2.85 ng/g (2.1±1.2%)	245±8 ng/g (100.0±3.5%)
penta-	122±5 ng/g (17.2±0.7%)	705±11 ng/g (100.0±1.6%)	77.7±28.7 ng/g (9.1±3.3%)	856±29 ng/g (100.0±3.3%)	22.8±11.9 ng/g (1.4±0.7%)	1640±100 ng/g (100.0±6.5%)
hexa-	370±38 ng/g (31.2±3.2%)	1180±110 ng/g (100.0±9.4%)	346±123 ng/g (20.3±7.2%)	1700±70 ng/g (100.0±4.3%)	175±71 ng/g (4.9±2.0%)	3570±180 ng/g (100.0±4.9%)
hepta-	232±4 ng/g (40.3±0.7%)	577±32 ng/g (100.0±5.6%)	321±98 ng/g (31.0±9.5%)	1040±10 ng/g (100.0±0.8%)	274±50 ng/g (12.9±2.4%)	2130±60 ng/g (100.0±2.9%)
octa-	74.9±15.5 ng/g (76.9±15.9%)	97.3±4.9 ng/g (100.0±5.0%)	90.0±20.0 ng/g (50.4±11.0%)	183±3 ng/g (100.0±1.9%)	96.3±9.6 ng/g (25.7±2.6%)	375±0 ng/g (100.0±0.1%)

Table C7. Numerical data for Figure 28: results of no-flow and flow column studies for 2 min mixing and 75-150 μm AC at 1, 3, and 24 months. Data are expressed as absolute total PCB uptake in PE (ng/g) with relative values compared to no-AC controls (%) in parentheses. Data are reported as average ± data range for duplicates.

AC application scenario		**1 month contact**	**3 months contact**	**24 months contact**
No-flow columns	control (no AC)	2730±130 ng/g (100.0±4.8%)	3900±110 ng/g (100.0±2.9%)	7990±350 ng/g (100.0±4.4%)
	2 min mixing, 75-150 μm AC	807±33 ng/g (29.6±1.2%)	844±270 ng/g (21.7±6.9%)	585±140 ng/g (7.3±1.7%)
Flow columns	control (no AC)	1630±100 ng/g (100.0±5.9%)	3760±210 ng/g (100.0±5.5%)	6180±480 ng/g (100.0±7.8%)
	2 min mixing, 75-150 μm AC	539±21 ng/g (33.0±1.3%)	931±78 ng/g (24.8±2.1%)	559±163 ng/g (9.1±2.6%)

Table C8. Numerical data for Figure 29: results of no-flow and flow column studies for different AC application scenarios at 3 months. Data are expressed as absolute total PCB uptake in PE (ng/g) with relative values compared to no-AC controls (%) in parentheses. Data are reported as average ± data range for duplicates.

AC application scenario	**No-flow columns**	**Flow columns**
control (no AC)	3900±110 ng/g (100.0±2.9%)	3760±210 ng/g (100.0±5.5%)
2 min mixing, 75-150 μm AC	844±270 ng/g (21.7±6.9%)	931±78 ng/g (24.8±2.1%)
30 min mixing, 75-150 μm AC	587±59 ng/g (15.1±1.5%)	478±27 ng/g (12.7±0.7%)
2×2 min mixing, 75-150 μm AC	852±52 ng/g (21.9±1.3%)	741±35 ng/g (19.7±0.9%)
2 min mixing, <45 μm AC	348±10 ng/g (8.9±0.3%)	443±9 ng/g (11.8±0.2%)
layered AC	4010±20 ng/g (102.9±0.5%)	3860±90 ng/g (102.7±2.5%)

Table C9. Numerical data for Figure 30: experimental and modeling results for sediment column studies with no-flow, 2 min mixing, and 75-150 μm AC for the model PCBs. Data are expressed as absolute PCB uptake in PE (ng/g) with relative values compared to no-AC controls ($C_{PE\_treated}/C_{PE\_untreated}$) in parentheses. Experimental data are reported as average ± data range for duplicates.

(a) PCB #101

AC application scenario		**1 month contact**	**3 months contact**	**24 months contact**
Experimental results	control (no AC)	182±18 ng/g	229±15 ng/g	469±20 ng/g
	2 min mixing, 75-150 μm AC	33.0±2.0 ng/g (0.181±0.011)	22.9±12.2 ng/g (0.111±0.053)	4.88±2.95 ng/g (0.010±0.006)
Modeling results	control (no AC)	170 ng/g	229 ng/g	551 ng/g
	2 min mixing, 75-150 μm AC	90.6 ng/g (0.533)	95.4 ng/g (0.417)	43.1 ng/g (0.078)

(b) PCB #153

AC application scenario		**1 month contact**	**3 months contact**	**24 months contact**
Experimental results	control (no AC)	257±18 ng/g	388±18 ng/g	852±36 ng/g
	2 min mixing, 75-150 μm AC	85.2±11.4 ng/g (0.332±0.045)	81.6±26.4 ng/g (0.210±0.068)	44.5±18.0 ng/g (0.052±0.021)
Modeling results	control (no AC)	385 ng/g	495 ng/g	1150 ng/g
	2 min mixing, 75-150 μm AC	246 ng/g (0.639)	283 ng/g (0.572)	298 ng/g (0.258)

(c) PCB #180

AC application scenario		**1 month contact**	**3 months contact**	**24 months contact**
Experimental results	control (no AC)	155±8 ng/g	276±0 ng/g	587±14 ng/g
	2 min mixing, 75-150 μm AC	64.4±0.8 ng/g (0.416±0.005)	89.2±27.9 ng/g (0.323±0.101)	83.5±13.7 ng/g (0.142±0.023)
Modeling results	control (no AC)	516 ng/g	633 ng/g	1330 ng/g
	2 min mixing, 75-150 μm AC	346 ng/g (0.671)	396 ng/g (0.625)	494 ng/g (0.372)

Table C10. Numerical data for Figure 33: Each replicate represents one tub, in which 8 to 10 individual vials containing a worm were submerged in artificial seawater. Data: numbering of worms, survival as S/So (0=dead, 1 = survived); initial weight [mg], W_0; final weight [mg] after 21 days exposure, W; the ratio W/W_0, total average, standard deviation, sample size (N). Worms that showed damage upon recovery (e.g. clipped tails) or did not depurate completely were omitted from further analysis, indicated with a blank in column for final weight (W).

Sand only		**with additional fish food supplied**			
Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	1	3.5	26.2	7.5
	2	1	4.3	20.9	4.9
	3	1	5.1	23	4.5
	4	1	5.4	19.7	3.6
	5	1	6.2	21.7	3.5
	6	1	7.8	23.9	3.1
	7	1	9.5	24.2	2.5
	8	1	10.3	26.2	2.5
	9	1	12.4	29.4	2.4
	10	1	15.1	25.3	1.7
Replicate 2					
N = 10	11	1	3.5	15.5	4.429
	12	1	4.2	23.2	5.524
	13	1	5.1	26.4	5.176
	14	1	5.3	32.8	6.189
	15	1	6.4	20	3.125
	16	1	7.7	22.3	2.896
	17	1	9.6	22.6	2.354
	18	1	10.3	27.1	2.631
	19	1	12.6	27.2	2.159
	20	1	14.9	39.7	2.664
Replicate 3					
N = 10	21	1	3.7	18.2	4.9
	22	1	3.8	14.8	3.9
	23	1	5.2	19.8	3.8
	24	1	5.2	21.6	4.2
	25	1	6.7	29.5	4.4
	26	1	7.6	22.2	2.9
	27	1	9.8	18.8	1.9
	28	1	10.2	24	2.4
	29	1	12.8	29.1	2.3
	30	1	14.2	28.5	2.0
Total					
average		**1.0**	**7.9**	**24.1**	**3.5**
stdev		**0.0**	**3.6**	**5.1**	**1.4**
N		**30**			**30**

Sand only		**(no food supplied)**			
Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	1	7.3	4.1	0.6
	2	1	6	3	0.5
	3	1	15	6.9	0.5
	4	1	14.3	10.2	0.7
	5	1	6.7	4.3	0.6
	6	1	5.1	3.5	0.7
	7	1	14.6	10.3	0.7
	8	1	16.6	6.8	0.4
	9	1	10.2	5.8	0.6
	10	1	3.4	1.8	0.5
Replicate 2	1	1	3.3	3.1	0.9
N = 10	2	1	3.8	4.8	1.3
	3	1	4.8		
	4	1	5.3	8.6	1.6
	5	1	6.1	5.2	0.9
	6	0	6.5	dead	
	7	1	7.9	3.6	0.5
	8	1	8.4	7.9	0.9
	9	1	11.4	7.1	0.6
	10	1	13.1	11.9	0.9
Replicate 3	11	1	3.3		
N = 10	12	1	3.5		
	13	1	4.9	6	1.2
	14	1	5.2		
	15	1	6.1	2.7	0.4
	16	1	6.4		
	17	1	8.1	7.4	0.9
	18	1	8.4	7.5	0.9
	19	1	11.5	11.4	1.0
	20	1	12.7	4.5	0.4
Replicate 4	21	1	3.4	3.7	1.1
N = 10	22	1	4.4	4.8	1.1
	23	1	4.9	4.1	0.8
	24	1	5.5	4.4	0.8
	25	1	6	4.4	0.7
	26	1	7.9	5.4	0.7
	27	1	9.4	7.8	0.8
	28	1	11.2	11.8	1.1
	29	1	11.7	10.8	0.9
	30	1	15.2	13.1	0.9
Total					
average		**1.0**	**8.0**	**6.4**	**0.8**
stdev		**0.2**	**3.9**	**3.0**	**0.3**
N		**40**			**34**

Site: **Holy Island**
Treatment: **none**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	1	1.6	1.2	0.8
	2	1	4	2.7	0.7
	3	1	4.2	2.6	0.6
	4	1	5.4	3.6	0.7
	5	1	5.5	4.2	0.8
	6	1	6.7	4.2	0.6
	7	1	6.9	5.8	0.8
	8	1	9.9	7.2	0.7
	9	1	10.2	8.1	0.8
	10	1	16.2	13	0.8
Replicate 2					
N = 10	11	1	1.9	1.6	0.8
	12	1	4		
	13	1	4.3		
	14	1	5.4	3.9	0.7
	15	1	5.6	4	0.7
	16	1	6.7	6.4	1.0
	17	0	6.9	dead	
	18	1	9.9	6.8	0.7
	19	1	10.6	5	0.5
	20	1	15	12.7	0.8
Replicate 3					
N = 10	21	1	2.2	2.5	1.1
	22	1	3.9		
	23	1	4.4		
	24	1	5.4		
	25	1	5.7	4	0.7
	26	1	6.7	5.1	0.8
	27	1	7.2	5.4	0.8
	28	1	9.9	6.9	0.7
	29	1	10.6	9.6	0.9
	30	1	14.9	10.8	0.7
Total					
average		**0.97**	**7.06**	**5.72**	**0.76**
stdev		**0.18**	**3.78**	**3.23**	**0.13**
N		**30**			24

Site: **Holy Island**
Treatment: **sand**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	1	25		
	2	1	3.8		
	3	1	4.4		
	4	1	5.4		
	5	1	5.8		
	6	1	6.6	4.2	0.6
	7	1	7.2	5.6	0.8
	8	1	9.8	7.7	0.8
	9	0	10.8	dead	
	10	1	14.8	13.2	0.9
Replicate 2					
N = 10	11	1	2.5		
	12	0	3.8	dead	
	13	0	4.5	dead	
	14	1	5.3	2.7	0.5
	15	1	5.8	4.2	0.7
	16	1	6.5	7.1	1.1
	17	0	7.3	dead	
	18	1	9.7	7.8	0.8
	19	1	11	7.4	0.7
	20	1	14.6	14.2	1.0
Replicate 3					
N = 10	21	1	2.6		
	22	1	3.8	3.6	0.9
	23	1	4.5		
	24	1	5.3	3.7	0.7
	25	1	5.8	5.1	0.9
	26	1	6.5		
	27	1	7.6	5.7	0.8
	28	1	9.6	8.5	0.9
	29	1	11.2	8.5	0.8
	30	1	14.5	8.8	0.6
Total					
average		**0.87**	**7.87**	**6.94**	**0.79**
stdev		**0.35**	**4.73**	**3.19**	**0.15**
N		**30**			**17**

Site: **Holy Island**
Treatment: **AC_m**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	0	3.1	dead	
	2	0	3.6	dead	
	3	1	4.8	3.3	0.7
	4	1	5		
	5	1	6.1	3.4	0.6
	6	1	6.2		
	7	1	8	5.8	0.7
	8	1	9	5.3	0.6
	9	1	12		
	10	1	12.8	10	0.8
Replicate 2					
N = 10	11	0	3.2	dead	
	12	0	3.5	dead	
	13	0	4.8	dead	
	14	1	3		
	15	1	6.1	3.8	0.6
	16	1	6.2	4.1	0.7
	17	1	8.2	4.8	0.6
	18	1	8.9	6.5	0.7
	19	1	12.1	7.6	0.6
	20	1	12.7	8.1	0.6
Replicate 3					
N = 10	21	1	3.2		
	22	1	3.3		
	23	1	4.9		
	24	1	4.9	4	0.8
	25	1	6.1	3.9	0.6
	26	1	6.1	2.2	0.4
	27	1	8.6	5	0.6
	28	1	8.7	6.5	0.7
	29	1	12.2	7.4	0.6
	30	1	12.2	5	0.4
Total					
average		**0.83**	**6.98**	**5.37**	**0.63**
stdev		**0.38**	**3.28**	**1.99**	**0.12**
N		**30**			**18**

Site: **Holy Island**
Treatment: **AC_c**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	1	2.9		
	2	1	3.7		
	3	1	4.6		
	4	1	5.2	2.8	0.5
	5	1	6	1.7	0.3
	6	1	6.5	3.9	0.6
	7	1	7.7		
	8	1	9.6	5.4	0.6
	9	1	11.6	8.7	0.8
	10	1	14.3	11.5	0.8
Replicate 2					
N = 10	11	1	3		
	12	0	3.6	dead	
	13	1	4.7		
	14	0	5	dead	
	15	0	6.1	dead	
	16	1	6.4	4.9	0.8
	17	1	7.9	6.7	0.8
	18	1	9.5	5.6	0.6
	19	1	11.6	10.8	0.9
	20	1	13.3	6.9	0.5
Replicate 3					
N = 10	21	1	3		
	22	1	3.7		
	23	1	4.8		
	24	0	5	dead	
	25	0	6.1	dead	
	26	1	6.3		
	27	1	7.9	5	0.6
	28	0	9	dead	
	29	1	12	9.7	0.8
	30	1	13.2	6.4	0.5
Total					
average		**0.80**	**6.70**	**6.39**	**0.65**
stdev		**0.41**	**3.23**	**3.01**	**0.17**
N		**30**			**14**

Site: **Blyth Harbor**
Treatment: **none**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	1	1.2	1.9	1.6
	2	1	3.7		
	3	1	3.7	5.1	1.4
	4	1	5.5	5.1	0.9
	5	1	5.5	6.1	1.1
	6	1	7.6		
	7	1	7.7	7.4	1.0
	8	1	9.6	9.2	1.0
	9	1	9.7	11.9	1.2
	10	1	16.2	12.5	0.8
Replicate 2					
N = 10	11	1	1.2	1.1	0.9
	12	1	3.6		
	13	1	3.8		
	14	1	5.5		
	15	1	5.6		
	16	1	7.6	6.7	0.9
	17	1	7.7	7.2	0.9
	18	1	9.5	9.5	1.0
	19	1	10	8.8	0.9
	20	1	16.2	14.5	0.9
Replicate 3					
N = 10	21	0	1.5	dead	
	22	1	3.5		
	23	1	3.9	4.1	1.1
	24	1	5.2	5.5	1.1
	25	1	5.7		
	26	1	7.5	6.7	0.9
	27	1	7.9		
	28	1	9.5		
	29	1	10	10.6	1.1
	30	1	15.1	16.3	1.1
Total					
average		**0.97**	**7.03**	**7.91**	**1.03**
stdev		**0.18**	**3.98**	**4.00**	**0.19**
N		**30**			**19**

Site: **Blyth Harbor**
Treatment: **sand**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	0	1.7	dead	
	2	0	3.5	dead	
	3	1	4		
	4	1	5.2	4.9	0.9
	5	1	5.7	6.6	1.2
	6	0	7.5	dead	
	7	1	7.9		
	8	1	9.4	7	0.7
	9	1	10	10.9	1.1
	10	1	14.9	12.5	0.8
Replicate 2					
N = 10	11	1	1.8	3	1.7
	12	1	3.3	2.9	0.9
	13	0	4	dead	
	14	1	5.1	5.9	1.2
	15	1	5.7	7.1	1.2
	16	1	7.4	7.2	1.0
	17	1	8	7.9	1.0
	18	1	9.2	9.9	1.1
	19	1	10.1	11.7	1.2
	20	1	14.9	15.1	1.0
Replicate 3					
N = 10	21	1	1.8	1.7	0.9
	22	0	3.3	dead	
	23	1	4.1	3.5	0.9
	24	1	5.1	4.8	0.9
	25	1	5.8	5.6	1.0
	26	1	7.4	6.9	0.9
	27	1	8	7.5	0.9
	28	1	9.2	5.4	0.6
	29	1	10.4	7.9	0.8
	30	1	14.5	16.8	1.2
Total					
average		**0.83**	**6.96**	**7.51**	**1.00**
stdev		**0.38**	**3.68**	**3.83**	**0.21**
N		**30**			**23**

Site: **Blyth Harbor**
Treatment: **AC_m**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	1	2.4		
	2	1	2.9		
	3	0	4.2	dead	
	4	1	4.8		
	5	1	6.5		
	6	1	7.2	4	0.6
	7	1	8.2	5.8	0.7
	8	1	8.8	7.3	0.8
	9	1	10.8		
	10	1	13.1		
Replicate 2					
N = 10	11	0	2.6	dead	
	12	1	2.9	dead	
	13	1	4.4		
	14	1	4.7	7.6	1.6
	15	1	6.5	2.7	0.4
	16	1	7.1	7	1.0
	17	1	8.3	5.7	0.7
	18	1	8.7	dead	
	19	1	10.8	7.5	0.7
	20	1	12.6	4	
Replicate 3					
N = 10	21	0	2.7	dead	
	22	0	2.9	dead	
	23	1	4.4	2.8	0.6
	24	1	4.7		
	25	1	6.5	4.1	0.6
	26	1	7.1	4.9	0.7
	27	1	8.4	5.7	0.7
	28	1	8.7	6.6	0.8
	29	1	10.9		
	30	1	12.4	13	1.0
Total					
average		**0.87**	**6.87**	**5.91**	**0.78**
stdev		**0.35**	**3.23**	**2.55**	**0.29**
N		**30**			**14**

Site: **Blyth Harbor**
Treatment: **AC_c**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N = 10	1	0	1.9	dead	
	2	0	3.3	dead	
	3	1	4.2		
	4	1	5.1		
	5	1	6.1	5.2	0.9
	6	1	7.4	6	0.8
	7	1	8.1	5.5	0.7
	8	1	9.1	8	0.9
	9	1	10.4	8.3	0.8
	10	1	14.4	13.1	0.9
Replicate 2					
N = 10	11	1	1.9	1.5	0.8
	12	1	3.2		
	13	0	4.2	dead	
	14	1	5	4.6	0.9
	15	0	6.1	dead	
	16	1	7.4		
	17	1	8.1	7	0.9
	18	1	9.1	7.5	0.8
	19	1	10.4	12.6	1.2
	20	1	14.2	4.8	
Replicate 3					
N = 10	21	0	2.4	dead	
	22	0	3	dead	
	23	0	4.2	dead	
	24	1	4.9		
	25	1	6.4	5.5	0.9
	26	1	7.3	5.2	0.7
	27	1	8.2		
	28	1	9	7.5	0.8
	29	1	10.4	9.1	0.9
	30	1	13.8	11.1	0.8
Total					
average		**0.77**	**6.47**	**7.11**	**0.85**
stdev		**0.43**	**3.33**	**2.93**	**0.12**
N		**30**			**16**

Site: **Hunters Point**

Treatment: **none**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	5	3.9	0.8
	2	1	7.4	5.7	0.8
	3	1	8.4	6.8	0.8
	4	1	9.3	7.8	0.8
	5	1	10.1	4.8	0.5
	6	1	11	9.2	0.8
	7	1	12	11.4	1.0
	8	1	13.9	9.3	0.7
Replicate 2					
N=8	9	1	6.7	5.9	0.9
	10	1	7.9	6.8	0.9
	11	1	8.6	7.2	0.8
	12	1	9.4	7.6	0.8
	13	1	10.5	6.5	0.6
	14	1	11.3	10.5	0.9
	15	1	13.1	8.8	0.7
	16	1	14.9	12.5	0.8
Replicate 3					
N=8	17	1	6.8	5.5	0.8
	18	1	8.3	7.8	0.9
	19	1	8.9	7.3	0.8
	20	1	10	7.4	0.7
	21	1	10.6	7.8	0.7
	22	1	11.7	7.9	0.7
	23	1	13.3	9.7	0.7
	24	1	15.6	13.8	0.9
Total					
average		**1.00**	**10.20**	**8.00**	**0.79**
stdev		**0.00**	**2.70**	**2.36**	**0.11**
N		**24**			**24**

Site: **Hunters Point**
Treatment: **sand**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	6	5.5	0.9
	2	1	7.4	5.9	0.8
	3	1	8.4	4.9	0.6
	4	1	9.3	6.8	0.7
	5	1	10.1	8.7	0.9
	6	1	10.9	7.2	0.7
	7	1	12.1	12.1	1.0
	8	1	13.8	12.1	0.9
Replicate 2					
N=8	9	1	6.5	5.2	0.8
	10	1	7.9	6.7	0.8
	11	1	8.6	7	0.8
	12	1	9.5	8.4	0.9
	13	1	10.5	8.6	0.8
	14	1	11.5	9.7	0.8
	15	1	13	9.2	0.7
	16	1	15.3	12.1	0.8
Replicate 3					
N=8	17	1	6.9	5.4	0.8
	18	1	8.2	4.6	0.6
	19	1	9	6.3	0.7
	20	1	9.9	6.8	0.7
	21	1	10.6	8.6	0.8
	22	1	11.7	7.9	0.7
	23	1	13.4	14.6	1.1
	24	1	15.5	11.7	0.8
Total					
average		**1.00**	**10.25**	**8.17**	**0.79**
stdev		**0.00**	**2.65**	**2.70**	**0.12**
N		**24**			**24**

Site: **Hunters Point**

Treatment: **AC_m**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	5.9	4.6	0.8
	2	1	8.1	5.7	0.7
	3	1	8.9	7.4	0.8
	4	1	10.2	8.5	0.8
	5	1	11.7	9.2	0.8
	6	1	13.3	9.4	0.7
	7	1	14.7	8.3	0.6
	8	1	16.5	12.7	0.8
Replicate 2					
N=8	9	1	6.7	6.1	0.9
	10	1	8.2	5.7	0.7
	11	1	9.7	8	0.8
	12	1	10.4	7.3	0.7
	13	1	12.1	8.7	0.7
	14	1	13.5	12.8	0.9
	15	1	15.5	12.6	0.8
	16	0	17.3	dead	
Replicate 3					
N=8	17	1	6.7	5.5	0.8
	18	1	8.9	7.5	0.8
	19	1	9.8	13.5	1.4
	20	1	11.3	9.4	0.8
	21	1	12.1	9.3	0.8
	22	1	14.6	12.1	0.8
	23	1	15.5	13.3	0.9
	24	0	18.5	dead	
Total					
average		**0.92**	**11.67**	**8.98**	**0.81**
stdev		**0.28**	**3.55**	**2.77**	**0.15**
N		**24**			**22**

Site: **Hunters Point**

Treatment: **AC_c**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	5.9	5.1	0.9
	2	1	8	5.2	0.7
	3	1	9	6.7	0.7
	4	1	10.2	13	1.3
	5	1	11.7	7.2	0.6
	6	1	13.3	10.9	0.8
	7	1	14.8	12.1	0.8
	8	1	16.5	14.1	0.9
Replicate 2					
N=8	9	1	6.5	6.2	1.0
	10	1	8.2	6.9	0.8
	11	1	9.7	12.1	1.2
	12	1	10.4	7.7	0.7
	13	1	12.1	10.8	0.9
	14	1	13.7	11.7	0.9
	15	1	15.4	11.1	0.7
	16	1	17.4	13.4	0.8
Replicate 3					
N=8	17	1	6.8	4.1	0.6
	18	1	8.8	6.9	0.8
	19	1	9.9	8.6	0.9
	20	1	11.1	9.4	0.8
	21	1	12.2	10	0.8
	22	1	14.3	13.7	1.0
	23	1	15.5	13.8	0.9
	24	1	18.5	14.7	0.8
Total					
average		**1.00**	**11.66**	**9.81**	**0.84**
stdev		**0.00**	**3.56**	**3.25**	**0.16**
N		**24**			**24**

Site: **Richmond**
Treatment: **none**

	worm I.D.	S/S0	Wo	W	W/W0
Replicate 1					
N=8	1	1	6.2	4.2	0.7
	2	1	7.2	5.3	0.7
	3	1	8.5	15.1	1.8
	4	0	9.3	dead	
	5	1	10.1	6.5	0.6
	6	1	10.9	7.8	0.7
	7	1	12.4	8.2	0.7
	8	1	13.7	10.6	0.8
Replicate 2					
N=8	9	1	6.4	4.8	0.8
	10	1	7.9	4.7	0.6
	11	1	8.6	5.6	0.7
	12	1	9.6	6.7	0.7
	13	1	10.4	7.1	0.7
	14	1	11.5	8.6	0.7
	15	1	12.9	10.1	0.8
	16	0	15.3	dead	

Replicate 3 8 out of 10 worms died early into the exposure
N=8 seems that there was a systematical issue with this replicate
- data omitted from further analysis

Total				
average	**0.88**	**10.06**	**7.52**	**0.78**
stdev	**0.34**	**2.63**	**2.94**	**0.29**
N	**16**			**14**

Site: **Richmond**
Treatment: **sand**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	6.3	4.7	0.7
	2	1	7.5	7.8	1.0
	3	1	9	6.4	0.7
	4	1	10.1	8	0.8
	5	1	11.8	8.6	0.7
	6	1	13	13.7	1.1
	7	1	14.8	14.2	1.0
	8	1	16.2	10.3	0.6
Replicate 2					
N=8	9	1	6.4	5.4	0.8
	10	1	8.5	6.1	0.7
	11	1	9.2	6.8	0.7
	12	1	10.7	9.7	0.9
	13	1	12	8.6	0.7
	14	1	14.2	10.8	0.8
	15	1	15.1	10.9	0.7
	16	1	17.7	13.6	0.8
Replicate 3					
N=8	17	1	7.3	7.1	1.0
	18	1	8.8	8.1	0.9
	19	1	10.1	9.6	1.0
	20	1	10.9	8.9	0.8
	21	1	12.5	10.6	0.8
	22	1	14.3	10.3	0.7
	23	1	15.8	11.1	0.7
	24	1	18.2	15	0.8
Total					
average		**1.00**	**11.68**	**9.43**	**0.82**
stdev		**0.00**	**3.52**	**2.79**	**0.12**
N		**24**			**24**

Site: **Richmond**

Treatment: **AC_m**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	7.1	4.7	0.7
	2	1	8.9	6.3	0.7
	3	1	10.5	8.6	0.8
	4	0	11.7	dead	
	5	1	12.6	9.4	0.7
	6	1	13.4	12.5	0.9
	7	1	14.6	8.6	0.6
	8	1	17.1	10.7	0.6
Replicate 2					
N=8	9	1	7.8	7.3	0.9
	10	1	9.4	7.8	0.8
	11	0	11	dead	
	12	1	12	9.1	0.8
	13	1	12.8	10	0.8
	14	1	13.8	11.7	0.8
	15	1	15.6	12.8	0.8
	16	1	17.7	12.8	0.7
Replicate 3					
N=8	17	1	8.4	10.9	1.3
	18	1	10.2	7.8	0.8
	19	1	11.2	5.6	0.5
	20	1	12.3	8.8	0.7
	21	1	13.2	19.6	1.5
	22	1	14.2	9.6	0.7
	23	1	16.7	20.3	1.2
	24	1	18.7	14.2	0.8
Total					
average		**0.92**	**12.54**	**10.41**	**0.83**
stdev		**0.28**	**3.16**	**3.92**	**0.23**
N		**24**			**22**

Site: **Richmond**

Treatment: **AC_c**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	0	6.6	dead	
	2	1	8.5	8	0.9
	3	1	10.7	9.1	0.9
	4	1	11.3	7.5	0.7
	5	1	13.3	10	0.8
	6	1	14.1	13	0.9
	7	1	15.5	15	1.0
	8	1	16.9	13	0.8
Replicate 2					
N=8	9	1	7.1	5.8	0.8
	10	1	9.5	6.2	0.7
	11	1	10.9	8.4	0.8
	12	1	12.7	9.6	0.8
	13	1	13.4	9.5	0.7
	14	1	14.9	14.2	1.0
	15	1	15.6	10.9	0.7
	16	1	20	17.9	0.9
Replicate 3					
N=8	17	1	8.2	6.9	0.8
	18	1	9.9	8.2	0.8
	19	1	11.1	7.4	0.7
	20	1	12.7	9.4	0.7
	21	1	13.9	11.4	0.8
	22	1	14.9	9.7	0.7
	23	1	16.6	10.4	0.6
	24	1	20.3	16.3	0.8
Total					
average		**0.96**	**12.86**	**10.34**	**0.79**
stdev		**0.20**	**3.67**	**3.23**	**0.10**
N		**24**			**23**

Site: **Blackwaters**
Treatment: **none**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	2.1		
	2	1	4.1		
	3	1	4.2	4.1	1.0
	4	1	5.9	6.6	1.1
	5	1	5.9	3.9	0.7
	6	1	7.1	4.8	0.7
	7	1	7.1	8.7	1.2
	8	1	9.8	5.9	0.6
Replicate 2					
N=8	9	1	2.5	3.4	1.4
	10	1	3.7	1.7	0.5
	11	1	4.5	3.8	0.8
	12	1	5.8	4.7	0.8
	13	1	6	4.9	0.8
	14	1	6.7		
	15	1	7.5	7.9	1.1
	16	1	8.8	8.9	1.0
Replicate 3					
N=8	17	1	3.1	2.3	0.7
	18	1	4.2		
	19	1	5.9		
	20	1	5.5	5.5	1.0
	21	1	6.1	6.4	1.0
	22	1	6.3	5.3	0.8
	23	1	7.7	6.2	0.8
	24	1	8.4	6.1	0.7
Total					
average		**1.00**	**6.03**	**5.32**	**0.88**
stdev		**0.00**	**1.84**	**1.94**	**0.22**
N		**24**			**19**

Site: **Blackwaters**
Treatment: **sand**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	2.1	3	1.4
	2	1	4.2		
	3	1	5.9	5.6	0.9
	4	1	7.3	6	0.8
	5	1	3.9	2.2	0.6
	6	1	5.9	5.8	1.0
	7	1	6.9	6.5	0.9
	8	1	9.5	4	0.4
Replicate 2					
N=8	9	1	2.7	3.2	1.2
	10	1	3.7	2.5	0.7
	11	1	4.5	3.5	0.8
	12	1	5.8	4.6	0.8
	13	1	6	5.4	0.9
	14	1	6.6	6.1	0.9
	15	1	7.6	8.4	1.1
	16	1	8.7	9	1.0
Replicate 3					
N=8	17	1	3.2	2.4	0.8
	18	1	3.6	3.3	0.9
	19	1	4.9	5.1	1.0
	20	1	5.4	4.9	0.9
	21	1	6.2		
	22	1	6.3	5.6	0.9
	23	1	7.8	6.9	0.9
	24	1	8.1	7.3	0.9
Total					
average		**1.00**	**5.70**	**5.06**	**0.90**
stdev		**0.00**	**1.95**	**1.91**	**0.21**
N		**24**			**22**

Site: **Blackwaters**

Treatment: **AC_m**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	4	4.2	1.1
	2	1	5.9	3.8	0.6
	3	1	7		
	4	1	9.5	8.9	0.9
	5	1	2.2	2.4	1.1
	6	1	4.3	3.3	0.8
	7	1	5.9	3.5	0.6
	8	1	7.4	5.2	0.7
Replicate 2					
N=8	9	1	2.9	1.4	0.5
	10	1	3.6	1.9	0.5
	11	1	4.6	5.8	1.3
	12	1	5.8	5.1	0.9
	13	1	6.1	3.8	0.6
	14	1	6.5	5.1	0.8
	15	1	7.7		
	16	0	8.6	dead	
Replicate 3					
N=8	17	1	3.2		
	18	1	3.4	5.8	1.7
	19	1	4.9	4.7	1.0
	20	1	5	3	0.6
	21	1	6.2	6.5	1.0
	22	1	6.3	4.4	0.7
	23	1	7.8	7.4	0.9
	24	1	8	8.3	1.0
Total					
average		**0.96**	**5.70**	**4.73**	**0.87**
stdev		**0.20**	**1.93**	**2.00**	**0.29**
N		**24**			**20**

Site: **Blackwaters**

Treatment: **AC_c**

	worm				
Replicate 1	**I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	2.5	2.9	1.2
	2	1	3.9	3	0.8
	3	1	4.3	3	0.7
	4	1	5.9	4	0.7
	5	1	5.9	6.5	1.1
	6	1	6.7	8.2	1.2
	7	1	7.4	5.1	0.7
	8	1	9.4	9.9	1.1
Replicate 2					
N=8	9	1	2.9	2.2	0.8
	10	1	3.6	3.4	0.9
	11	1	4.7	3.8	0.8
	12	0	5.7	dead	
	13	1	6.1	4.2	0.7
	14	1	6.5	7.9	1.2
	15	1	7.7	7.2	0.9
	16	1	8.5	7.2	0.8
Replicate 3					
N=8	17	1	3.2	4	1.3
	18	1	3.3	3.2	1.0
	19	1	4.9	4.6	0.9
	20	1	5	3.9	0.8
	21	1	6.2	4.7	0.8
	22	1	6.3	3.5	0.6
	23	1	7.9	8.1	1.0
	24	1	8	6.2	0.8
Total					
average		**0.96**	**5.69**	**5.07**	**0.90**
stdev		**0.20**	**1.90**	**2.13**	**0.20**
N		**24**			**23**

Table C11. Numerical data for Figure 34: Each replicate represents one tub, in which 8 individual vials containing a worm were submerged in artificial seawater. Data: numbering of worms, survival as S/So (0=dead, 1 = survived); initial weight [mg], W_0; final weight [mg] after 21 days exposure, W; the ratio W/W_0, total average, standard deviation, sample size (N). Worms that showed damage upon recovery (e.g. clipped tails) or did not depurate completely were omitted from further analysis, indicated with a blank in column for final weight (W).

Site:	**Hunters Point**					
		Without food supply				
Treatment:	**none**	**PLEASE SEE TABLE C10**				
Site:	**Hunters Point**	**without food supply**				
Treatment:	**AC_m (5%)**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	6.7	4.6	0.7
		2	1	9.3	7.7	0.8
		3	1	10.5	8.9	0.8
		4	1	11.8	10.8	0.9
		5	1	12.4	12.5	1.0
		6	1	13.5	10.3	0.8
		7	1	14.5	13.4	0.9
		8	1	17.3	16.4	0.9
	Replicate 2					
	N=8	9	1	8.1	7	0.9
		10	1	9.3	8.4	0.9
		11	1	11.2	9.8	0.9
		12	1	11.8	9.4	0.8
		13	1	12.9	13.1	1.0
		14	1	13.6	8.6	0.6
		15	1	15.9	13.4	0.8
		16	1	17.5	14.7	0.8
	Replicate 3					
	N=8	17	1	8.2	6.3	0.8
		18	1	10.3	7.2	0.7
		19	1	11.2	8.2	0.7
		20	0	12.3	dead	
		21	1	13	10.6	0.8
		22	1	14.3	10.3	0.7
		23	1	16	12.8	0.8
		24	1	19.6	13.9	0.7
	Total					
	average		**0.96**	**12.55**	**10.36**	**0.82**
	stdev		**0.20**	**3.21**	**3.00**	**0.10**
	N		**24**			**23**

Site:	**Hunters Point**	**without food supply**				
Treatment:	**AC_m (20%)**	**PLEASE SEE TABLE C10**				
Site:	**Hunters Point**	**without food supply**				
Treatment:	**AC_f (5%)**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	0	4.7	dead	
		2	1	7.8	5.2	0.7
		3	1	9.2	6	0.7
		4	1	10.2	7.8	0.8
		5	1	11	6.7	0.6
		6	1	12.1	12.2	1.0
		7	1	12.9	12.5	1.0
		8	1	13.7	7	0.5
	Replicate 2					
	N=8	9	1	14.6	9.8	0.7
		10	1	15.3	11.7	0.8
		11	1	15.7	12.3	0.8
		12	1	18.1	12.3	0.7
		13	1	7.6	6.4	0.8
		14	1	8.9	6.6	0.7
		15	1	10.2	5.9	0.6
		16	0	10.9	dead	
	Replicate 3					
	N=8	17	1	12	9.1	0.8
		18	1	12.9	11.2	0.9
		19	1	13.5	10.3	0.8
		20	1	14.6	10.5	0.7
		21	1	15.3	14.7	1.0
		22	1	15.6	10.2	0.7
		23	1	17.5	5.3	0.3
		24	1	22	22.8	1.0
	Total					
	average		**0.92**	**12.76**	**9.84**	**0.74**
	stdev		**0.28**	**3.84**	**4.02**	**0.17**
	N		**24**			**22**

Site:	**Hunters Point**	**with additional food supply**				
Treatment:	**none**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	4.9	24.4	5.0
		2	1	6.8	21.6	3.2
		3	1	7.8	29.2	3.7
		4	1	8.4	27.4	3.3
		5	1	8.9	31.9	3.6
		6	1	9.4	30.2	3.2
		7	1	10	33	3.3
		8	1	10.6	32.5	3.1
	Replicate 2					
	N=8	9	1	11.2	31.9	2.8
		10	1	12	32.2	2.7
		11	1	13.1	31.6	2.4
		12	1	14.5	38.9	2.7
		13	1	6.8	19.4	2.9
		14	1	7.7	24.8	3.2
		15	1	8.4	30.6	3.6
		16	1	8.9	26.6	3.0
	Replicate 3					
	N=8	17	1	9.3	24.3	2.6
		18	1	10	32.4	3.2
		19	1	10.5	28.3	2.7
		20	1	11	26.3	2.4
		21	1	11.8	40	3.4
		22	1	13.1	26	2.0
		23	1	14.2	27.7	2.0
		24	1	16.2	31.2	1.9
	Total					
	average		**1.00**	**10.23**	**29.27**	**2.99**
	stdev		**0.00**	**2.72**	**4.82**	**0.67**
	N		**24**			**24**

Site:	**Hunters Point**	**with additional food supply**				
Treatment:	**AC_m (5%)**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	7.2	26.3	3.7
		2	1	8.6	28.7	3.3
		3	1	9.7	28.7	3.0
		4	1	10.5	28.1	2.7
		5	1	11.3	31.7	2.8
		6	1	12	37.5	3.1
		7	1	12.6	25.9	2.1
		8	1	13.2	21.8	1.7
	Replicate 2					
	N=8	9	1	13.9	26.9	1.9
		10	1	14.7	31.4	2.1
		11	1	16.8	28.1	1.7
		12	1	18	29.1	1.6
		13	1	7.8	21.9	2.8
		14	1	8.7	30	3.4
		15	1	10.1	29.5	2.9
		16	1	11	35.7	3.2
	Replicate 3					
	N=8	17	1	11.6	41.7	3.6
		18	1	12.1	24.2	2.0
		19	1	12.7	24	1.9
		20	1	13.3	25.5	1.9
		21	1	13.9	33.9	2.4
		22	1	15.1	24.8	1.6
		23	1	16.9	36.4	2.2
		24	1	18.4	32.7	1.8
	Total					
	average		**1.00**	**12.50**	**29.35**	**2.48**
	stdev		**0.00**	**3.11**	**5.05**	**0.69**
	N		**24**			**24**

Site:	**Hunters Point**	**with additional food supply**				
Treatment:	**AC_m (20%)**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	6.2	20.9	3.4
		2	1	6.9	25.8	3.7
		3	1	8.4	27.7	3.3
		4	1	9	22.7	2.5
		5	1	9.9	26.9	2.7
		6	1	10.5	28.6	2.7
		7	1	11.8	21.7	1.8
		8	1	12.4	34.1	2.8
	Replicate 2					
	N=8	9	1	14	23.8	1.7
		10	1	14.8	26.5	1.8
		11	1	15.6	34.3	2.2
		12	1	17.6	30	1.7
		13	1	6.4	28	4.4
		14	1	7.7	25.1	3.3
		15	1	8.8	33.7	3.8
		16	1	9.5	26.3	2.8
	Replicate 3					
	N=8	17	1	10.1	23.4	2.3
		18	1	11	30.4	2.8
		19	1	12.1	25.2	2.1
		20	1	13.1	21.8	1.7
		21	1	14.3	25.6	1.8
		22	1	15.3	27.2	1.8
		23	1	16.3	35.1	2.2
		24	1	18.2	26.9	1.5
	Total					
	average		**1.00**	**11.66**	**27.15**	**2.53**
	stdev		**0.00**	**3.53**	**4.08**	**0.79**
	N		**24**			**24**

Site:	**Hunters Point**	**with additional food supply**				
Treatment:	**AC_f (5%)**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	6.5	21.4	3.3
		2	1	8	19.6	2.5
		3	1	9.2	15	1.6
		4	1	10.4	23	2.2
		5	1	11.1	25.5	2.3
		6	1	12.7	25.5	2.0
		7	1	13	21.3	1.6
		8	1	13.8	27.7	2.0
	Replicate 2					
	N=8	9	1	14.7	29.8	2.0
		10	1	15.4	24.2	1.6
		11	1	16.1	27.4	1.7
		12	1	18.5	27.4	1.5
		13	1	7.3	17.7	2.4
		14	1	8.8	17.3	2.0
		15	1	10.1	27.8	2.8
		16	1	10.9	21.4	2.0
	Replicate 3					
	N=8	17	1	11.5	25.6	2.2
		18	1	12.8	24.8	1.9
		19	1	13.5	20.6	1.5
		20	1	14.5	22.6	1.6
		21	1	15.3	26.2	1.7
		22	1	15.6	28.8	1.8
		23	1	17.3	32.2	1.9
		24	1	21.4	36.8	1.7
	Total					
	average		**1.00**	**12.85**	**24.57**	**1.99**
	stdev		**0.00**	**3.67**	**4.95**	**0.43**
	N		**24**			**24**

Site: Blackwater **without food supply**
Treatment: none **PLEASE SEE TABLE C10**

Site: Blackwater **without food supply**
Treatment: AC_m (5%)

Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	6.8	6	0.9
	2	1	9.1	9	1.0
	3	1	10.5	10.3	1.0
	4	1	11.8	10.4	0.9
	5	1	12.5	10.7	0.9
	6	1	13.5	11.2	0.8
	7	1	14.6		
	8	1	17.1	14.8	0.9
Replicate 2					
N=8	9	1	8.1	7.6	0.9
	10	1	9.3	8.2	0.9
	11	1	11.1	9.9	0.9
	12	1	11.9	14.1	1.2
	13	1	12.8	13.9	1.1
	14	1	13.8	11.1	0.8
	15	1	15.7	14.8	0.9
	16	1	17.5	16.2	0.9
Replicate 3					
N=8	17	1	8.2	8.9	1.1
	18	1	10.3	9.7	0.9
	19	1	11.2	9.7	0.9
	20	1	12.3	9.7	0.8
	21	1	13.1	12.1	0.9
	22	1	14.2	13.8	1.0
	23	1	16.3	12.9	0.8
	24	1	19.4	12.9	0.7
Total					
average		**1.00**	**12.55**	**11.21**	**0.91**
stdev		**0.00**	**3.19**	**2.60**	**0.11**
N		**24**			**23**

Site: Blackwater **without food supply**
Treatment: none **PLEASE SEE TABLE C10**

Site: Blackwater **without food supply**
Treatment: AC_f (5%)

Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
N=8	1	1	6.1	7.1	1.2
	2	1	8	7.8	1.0
	3	1	9.2	8.7	0.9
	4	1	10.3	9.9	1.0
	5	1	11	10.3	0.9
	6	0	12.2	dead	
	7	0	13	dead	
	8	1	13.7	11.7	0.9
Replicate 2					
N=8	9	0	14.6	dead	
	10	1	15.4	10.4	0.7
	11	1	16	14.1	0.9
	12	1	18.2	14.4	0.8
	13	1	7.3	7.8	1.1
	14	1	8.9	6.8	0.8
	15	1	10.2	8.7	0.9
	16	0	10.9	dead	
Replicate 3					
N=8	17	1	11.9	11.2	0.9
	18	1	12.8	8.1	0.6
	19	1	13.5	8.7	0.6
	20	0	14.6	dead	
	21	1	15.3	9.8	0.6
	22	1	15.6	11	0.7
	23	1	17.4	9.5	0.5
	24	1	21.9	15.9	0.7
Total					
average		**0.79**	**12.83**	**10.10**	**0.83**
stdev		**0.41**	**3.73**	**2.51**	**0.17**
N		**24**			**19**

Site:	**Blackwater**	**with additional food supply**				
Treatment:	**none**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	6.3	23.2	3.7
		2	1	7.1	30	4.2
		3	1	8	26	3.3
		4	1	8.5	21.5	2.5
		5	1	9.1	28.7	3.2
		6	1	9.6	29.3	3.1
		7	1	10.2	24.2	2.4
		8	1	10.7	29.9	2.8
	Replicate 2					
	N=8	9	1	11.5	28.6	2.5
		10	1	12.6	31.9	2.5
		11	1	13.6	24.5	1.8
		12	1	15.4	25.4	1.6
		13	1	6.3	21.8	3.5
		14	1	7.2	26.4	3.7
		15	1	8	24.7	3.1
		16	1	8.5	23	2.7
	Replicate 3					
	N=8	17	1	9.2	23.5	2.6
		18	1	9.8	27	2.8
		19	1	10.2	31.4	3.1
		20	1	10.9	29.2	2.7
		21	1	11.6	23.6	2.0
		22	1	12.7	26.1	2.1
		23	1	13.7	25.2	1.8
		24	1	15.4	26	1.7
	Total					
	average		**1.00**	**10.25**	**26.30**	**2.71**
	stdev		**0.00**	**2.65**	**2.98**	**0.68**
	N		**24**			**24**

Site:	**Blackwater**	**with additional food supply**				
Treatment:	**AC_m (5%)**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	7.2	26.5	3.7
		2	1	8.6	29	3.4
		3	1	9.7	30.9	3.2
		4	1	10.9	26.4	2.4
		5	1	11.4	30	2.6
		6	1	12	28.7	2.4
		7	1	12.7	26.7	2.1
		8	1	13.2	32.9	2.5
	Replicate 2					
	N=8	9	1	13.9	37.9	2.7
		10	1	14.8	33.8	2.3
		11	1	16.8	32.3	1.9
		12	1	18.1	31.4	1.7
		13	1	7.5	31.8	4.2
		14	1	8.6	20.5	2.4
		15	1	9.9	25.8	2.6
		16	1	10.9	26.6	2.4
	Replicate 3					
	N=8	17	1	11.5	27.1	2.4
		18	1	12.1	30.1	2.5
		19	1	12.7	27.8	2.2
		20	1	13.3	40	3.0
		21	1	13.9	29.2	2.1
		22	1	14.8	36.3	2.5
		23	1	16.9	32.6	1.9
		24	1	18.3	33.3	1.8
	Total					
	average		**1.00**	**12.49**	**30.32**	**2.54**
	stdev		**0.00**	**3.12**	**4.29**	**0.60**
	N		**24**			**24**

Site:	**Blackwater**	**with additional food supply**				
Treatment:	**AC_m (20%)**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	6.4	24.1	3.8
		2	1	7.4	27.3	3.7
		3	1	8.5	25.2	3.0
		4	1	9.1	28.5	3.1
		5	1	10.1	23.3	2.3
		6	1	10.8	25.5	2.4
		7	1	11.9	23	1.9
		8	1	12.5	25.8	2.1
	Replicate 2					
	N=8	9	1	14.2	27.4	1.9
		10	1	15	27.5	1.8
		11	1	16	26.6	1.7
		12	1	17.8	35.1	2.0
		13	1	6.4	28.2	4.4
		14	1	7.5	28.5	3.8
		15	1	8.6	28.2	3.3
		16	1	9.2	26.2	2.8
	Replicate 3					
	N=8	17	1	10.1	29.6	2.9
		18	1	10.8	28.4	2.6
		19	1	12	24.6	2.1
		20	1	12.9	30.5	2.4
		21	1	14.2	31.7	2.2
		22	1	15	30.3	2.0
		23	1	16.1	32.4	2.0
		24	1	17.9	25.2	1.4
	Total					
	average		**1.00**	**11.68**	**27.63**	**2.57**
	stdev		**0.00**	**3.50**	**2.96**	**0.78**
	N		**24**			**24**

Site:	**Blackwater**	**with additional food supply**				
Treatment:	**AC_f (5%)**					
	Replicate 1	**worm I.D.**	**S/S0**	**Wo**	**W**	**W/W0**
	N=8	1	1	6.6	23.3	3.5
		2	1	8.1	24.1	3.0
		3	1	9.4	23.4	2.5
		4	1	10.6	24.3	2.3
		5	1	11.1	25.4	2.3
		6	1	12.7	29.1	2.3
		7	1	13.2	21.6	1.6
		8	1	13.9	30.6	2.2
	Replicate 2					
	N=8	9	1	14.7	27.9	1.9
		10	1	15.5	22.4	1.4
		11	1	16.3	37	2.3
		12	1	18.8	28.7	1.5
		13	1	7.3	26.1	3.6
		14	1	8.6	27.7	3.2
		15	1	10.1	23	2.3
		16	1	10.9	25.6	2.3
	Replicate 3					
	N=8	17	1	11.4	26.1	2.3
		18	1	12.8	21.7	1.7
		19	1	13.4	25	1.9
		20	1	14.2	23.2	1.6
		21	1	15.3	29.1	1.9
		22	1	15.6	25.4	1.6
		23	1	16.9	31.5	1.9
		24	1	20.4	27.2	1.3
	Total					
	average		**1.00**	**12.83**	**26.23**	**2.19**
	stdev		**0.00**	**3.56**	**3.59**	**0.62**
	N		**24**			**24**

Table C12. Numerical data for Figure 35: Each replicate represents one tub, in which 10 individual vials containing a worm were submerged in artificial seawater. Worms that showed damage upon recovery (e.g. clipped tails) or did not depurate completely were omitted from further analysis, indicated with a blank in column for final weight (W).

		% survival out of 10 worms / replicate	lnS/So
Day 0	repl 1	100	0.00
	repl2	100	0.00
	repl3	100	0.00
Day 4	repl 1	100	0.00
	repl2	100	0.00
	repl3	100	0.00
Day 11	repl 1	100	0.00
	repl2	93.33	-0.07
	repl3	93.33	-0.07
Day 21	repl 1	96.67	-0.03
	repl2	100	0.00
	repl3	100	0.00
	repl4	100	0.00
Day 28	repl 1	86.67	-0.14
	repl2	93.33	-0.07
	repl3	93.33	-0.07
	repl4	80	-0.22
Day 21	repl 1	100	0.00
w/ food	repl2	100	0.00
	repl3	100	0.00

Day 4

Replicate 1	worm I.D.	Wo	W	ln(dW)
N = 10	1	2.9	3.9	-1.1
	2	4.1	3.7	-2.3
	3	4.5	3.8	-1.9
	4	5.4	3.8	-1.2
	5	5.8	5.2	-2.3
	6	6.8	7	-3.5
	7	7.7	6.8	-2.1
	8	8.5	9.1	-2.7
	9	9.6	8.9	-2.6
	10	14.6	12.8	-2.1
Replicate 2	11	3	3.1	-3.4
N = 10	12	3.9	4.6	-1.7
	13	4.6	4.4	-3.1
	14	5.4	4.7	-2.0
	15	5.8	7.2	-1.4
	16	6.6	2.6	-0.5
	17	7.7	6.2	-1.6
	18	8.5	8.4	-4.4
	19	10.1	9.6	-3.0
	20	14.5	15.4	-2.8
Replicate 3				
N = 10	21	1.9	1.4	-1.3
	22	4.5	4.6	-3.8
	23	4.7	4.1	-2.1
	24	5.8	5.5	-3.0
	25	6	5.6	-2.7
	26	9	7.7	-1.9
	27	9.1	6.3	-1.2
	28	11.3	11.1	-4.0
	29	11.4	10.4	-2.4
	30	18.5	13.5	-1.3
		average		-2.3
		stdev		0.95

Day 11

Replicate 1	worm I.D.	Wo	W	ln(dW)
N = 10	1	3	2.9	-3.4
	2	3.9		
	3	4.6	5.1	-2.2
	4	5.3	5.1	-3.3
	5	6	5.6	-2.7
	6	6.5	5.5	-1.9
	7	7.8		
	8	8.5	8.6	-4.4
	9	10.6	9	-1.9
	10	13.8	14.3	-3.3
Replicate 2	11	3	dead	
N = 10	12	3.8		
	13	4.7	dead	
	14	5.3	1.8	-0.4
	15	6	5.3	-2.1
	16	6.5	5.3	-1.7
	17	7.8	7.8	
	18	8.5	7.4	-2.0
	19	10.9	12.2	-2.1
	20	13.5	9.2	-1.1
Replicate 3				
N = 10	21	3.2	2.5	-1.5
	22	4.5	5.4	-1.6
	23	4.8	3.9	-1.7
	24	5.8	4	-1.2
	25	6	5.2	-2.0
	26	9	9.4	-3.1
	27	9.4	6.6	-1.2
	28	11.3	9.1	-1.6
	29	11.4	dead	
	30	16.5	13.1	-1.6
		average		-2.1
		stdev		0.91

Day 21

	worm			
Replicate 1	**I.D.**	**Wo**	**W**	**ln(dW)**
N = 10	1	3.3	3.1	-0.6
	2	3.8		
	3	4.8	4.1	-1.9
	4	5.3	8.6	-0.5
	5	6.1	5.2	-1.9
	6	6.5	dead	
	7	7.9	3.6	-0.6
	8	8.4	7.9	-2.8
	9	11.4	7.1	-1.0
	10	13.1	11.9	-2.4
Replicate 2	11	3.3		
N = 10	12	3.5		
	13	4.9	6	-1.5
	14	5.2		
	15	6.1	2.7	-0.6
	16	6.4		
	17	8.1	7.4	-2.4
	18	8.4	7.5	-2.2
	19	11.5	11.4	-4.7
	20	12.7	4.5	-0.4
Replicate 3				
N = 10	21	3.4	3.7	-2.4
	22	4.4	4.8	-2.4
	23	4.9	4.1	-1.8
	24	5.5	4.4	-1.6
	25	6	4.4	-1.3
	26	7.9	5.4	-1.2
	27	9.4	7.8	-1.8
	28	11.2	11.8	-2.9
	29	11.7	10.8	-2.6
	30	15.2	13.1	-2.0
		average		-1.8
		stdev		1.00

Day 28

	worm			
Replicate 1	**I.D.**	**Wo**	**W**	**ln(dW)**
N = 10	1	1.6		
	2	4.2		
	3	4.2		
	4	5.4		
	5	5.5	4.1	-1.8
	6	7.3		
	7	7.4	3.2	-1.4
	8	9		
	9	9		
	10	17		
Replicate 2	11	1.8		
N = 10	12	4.1	5.2	-3.0
	13	4.3		
	14	5.4	6.2	-1.5
	15	5.6	3.5	-1.3
	16	7	6	-1.9
	17	7.5	2.9	-1.3
	18	8.9		
	19	9		
	20	15.9		
		average		-1.8
		stdev		0.61

Day 21

Replicate 1	worm I.D.	Wo	W	ln(dW)
N = 10	1	3.5	26.2	1.9
	2	4.3	20.9	1.4
	3	5.1	23	1.3
	4	5.4	19.7	1.0
	5	6.2	21.7	0.9
	6	7.8	23.9	0.7
	7	9.5	24.2	0.4
	8	10.3	26.2	0.4
	9	12.4	29.4	0.3
	10	15.1	25.3	-0.4
Replicate 2	11	3.5	15.5	1.2
N = 10	12	4.2	23.2	1.5
	13	5.1	26.4	1.4
	14	5.3	32.8	1.6
	15	6.4	20	0.8
	16	7.7	22.3	0.6
	17	9.6	22.6	0.3
	18	10.3	27.1	0.5
	19	12.6	27.2	0.1
	20	14.9	39.7	0.5
Replicate 3				
N = 10	21	3.7	18.2	1.4
	22	3.8	14.8	1.1
	23	5.2	19.8	1.0
	24	5.2	21.6	1.1
	25	6.7	29.5	1.2
	26	7.6	22.2	0.7
	27	9.8	18.8	-0.1
	28	10.2	24	0.3
	29	12.8	29.1	0.2
	30	14.2	28.5	0.0
		average		0.8
		stdev		0.56

Table C13. Numerical data for Figure 36: Lipid, protein and glycogen content for individual worms after exposure to various media. All treatment refer to the 20% amendments of the indicated material. N = 3-6.

Matrix	treatment	repl	% lipid	average	stdev
Holy Island	**none**	1	0.11		
		2	0.04		
		3	0.36	**0.17**	**0.16**
Holy Island	**sand**	1	0.31		
		2	0.28		
		3	0.58	**0.39**	**0.17**
Holy Island	**AC_m**	1	0.30		
		2	0.57		
		3	0.28	**0.38**	**0.16**
Holy Island	**AC_c**	1	0.32		
		2	0.70		
		3	0.24	**0.42**	**0.25**
Blyth Harbor	**none**	1	0.27		
		2	0.34		
		3	0.49	**0.37**	**0.11**
Blyth Harbor	**sand**	1	0.67		
		2	0.62		
		3	0.07	**0.45**	**0.34**
Blyth Harbor	**AC_m**	1	0.45		
		2	0.46		
		3	0.35	**0.42**	**0.06**
Blyth Harbor	**AC_c**	1	0.31		
		2	0.36		
		3	0.31	**0.33**	**0.03**
Blackwater	**none**	1	0.22		
		2	0.30		
		3	0.14	**0.22**	**0.08**
Blackwater	**sand**	1	0.33		
		2	0.45		
		3	0.24	**0.34**	**0.11**
Blackwater	**AC_m**	1	0.47		
		2	0.28		
		3	0.26	**0.34**	**0.11**
Blackwater	**AC_c**	1	0.39		
		2	0.36		
		3	0.30	**0.35**	**0.05**

by wet weight of the individual organism

Matrix	treatment	repl	% lipid	average	stdev
Hunters Point	**none**	1	1.61		
		2	1.11		
		3	1.05		
		4	1.07		
		5	1.08		
		6	0.78	**1.12**	**0.27**
Hunters Point	**sand**	1	1.22		
		2	1.03		
		3	0.95		
		4	1.09		
		5	1.28		
		6	1.06	**1.10**	**0.12**
Hunters Point	**AC_m**	1	1.12		
		2	0.95		
		3	1.21		
		4	0.92		
		5	0.98		
		6	0.85	**1.00**	**0.13**
Hunters Point	**AC_c**	1	0.88		
		2	1.06		
		3	1.09		
		4	0.98		
		5	0.81		
		6	1.80	**1.10**	**0.36**

Matrix	treatment	repl	% lipid	average	stdev
Richmond	**none**	1	1.10		
		2	1.06		
		3	1.13		
		4	0.99		
		5	1.15		
		6		**1.08**	**0.06**
Richmond	**sand**	1	1.24		
		2	0.95		
		3	1.03		
		4	0.88		
		5	0.80		
		6	0.88	**0.96**	**0.16**
Richmond	**AC_m**	1	1.24		
		2	1.08		
		3	0.85		
		4	0.83		
		5	0.73		
		6	0.92	**0.94**	**0.19**
Richmond	**AC_c**	1	0.87		
		2	0.75		
		3	0.86		
		4	1.23		
		5	0.98		
		6	1.24	**0.99**	**0.20**

by wet weight of the individual organism

Matrix	treatment	repl	% protein	average	stdev
Holy Island	**none**	1	2.64		
		2	2.53		
		3	3.66	**2.94**	**0.62**
Holy Island	**sand**	1	7.40		
		2	3.52		
		3	2.57	**4.50**	**2.56**
Holy Island	**AC_m**	1	2.59		
		2	2.61		
		3	2.64	**2.61**	**0.02**
Holy Island	**AC_c**	1	2.74		
		2	2.46		
		3	2.01	**2.40**	**0.37**
Blyth Harbor	**none**	1	4.70		
		2	2.10		
		3	2.09	**2.96**	**1.50**
Blyth Harbor	**sand**	1	2.39		
		2	3.00		
		3	2.33	**2.57**	**0.37**
Blyth Harbor	**AC_m**	1	2.45		
		2	2.14		
		3	0.92	**1.84**	**0.81**
Blyth Harbor	**AC_c**	1	2.16		
		2	3.00		
		3	1.50	**2.22**	**0.75**
Blackwater	**none**	1	2.96		
		2	3.20		
		3	3.04	**3.06**	**0.12**
Blackwater	**sand**	1	2.93		
		2	2.62		
		3	2.31	**2.62**	**0.31**
Blackwater	**AC_m**	1	3.29		
		2	2.13		
		3	1.87	**2.43**	**0.75**
Blackwater	**AC_c**	1	2.00		
		2	3.09		
		3	2.48	**2.52**	**0.55**

by wet weight of the individual organism

Matrix	treatment	repl	% protein	average	stdev
Hunters Point	**none**	1	4.15		
		2	5.88		
		3	3.62		
		4	3.01		
		5	3.69		
		6	3.82	**4.03**	**0.98**
Hunters Point	**sand**	1	4.26		
		2	3.75		
		3	3.30		
		4	3.18		
		5	4.26		
		6	2.03	**3.46**	**0.84**
Hunters Point	**AC_m**	1	4.53		
		2	3.39		
		3	3.78		
		4	2.68		
		5	3.20		
		6	3.26	**3.47**	**0.63**
Hunters Point	**AC_c**	1	5.19		
		2	4.73		
		3	2.77		
		4	3.45		
		5	4.21		
		6	3.04	**3.90**	**0.97**

Matrix	treatment	repl	% protein	average	stdev
Richmond	**none**	1	3.91		
		2	3.57		
		3	4.40		
		4	3.76		
		5	1.50		
		6		**3.43**	**1.12**
Richmond	**sand**	1	2.96		
		2	3.83		
		3	3.42		
		4	4.10		
		5	3.20		
		6	3.42	**3.49**	**0.42**
Richmond	**AC_m**	1	4.55		
		2	3.36		
		3	3.18		
		4	3.59		
		5	2.72		
		6	2.01	**3.24**	**0.85**
Richmond	**AC_c**	1	3.00		
		2	2.57		
		3	2.82		
		4	3.39		
		5	4.00		
		6	3.75	**3.25**	**0.56**

by wet weight of the individual organism

Matrix	treatment	repl	% glycogen	average	stdev
Holy Island	**none**	1	0.46		
		2	0.41		
		3	0.45	**0.44**	**0.03**
Holy Island	**sand**	1	0.46		
		2	0.28		
		3	0.68	**0.48**	**0.20**
Holy Island	**AC_m**	1	0.34		
		2	0.50		
		3	0.29	**0.38**	**0.11**
Holy Island	**AC_c**	1	0.54		
		2	0.60		
		3	0.38	**0.51**	**0.11**
Blyth Harbor	**none**	1	0.22		
		2	0.18		
		3	0.20	**0.20**	**0.02**
Blyth Harbor	**sand**	1	0.18		
		2	0.33		
		3	0.19	**0.24**	**0.09**
Blyth Harbor	**AC_m**	1	0.24		
		2	0.62		
		3	0.31	**0.39**	**0.20**
Blyth Harbor	**AC_c**	1	0.45		
		2	0.30		
		3	0.44	**0.40**	**0.08**
Blackwater	**none**	1	0.79		
		2	1.00		
		3	0.76	**0.85**	**0.13**
Blackwater	**sand**	1	1.11		
		2	1.04		
		3	0.78	**0.98**	**0.17**
Blackwater	**AC_m**	1	0.72		
		2	0.63		
		3	0.60	**0.65**	**0.06**
Blackwater	**AC_c**	1	1.11		
		2	1.24		
		3	1.02	**1.12**	**0.11**

by wet weight of the individual organism

Matrix	treatment	repl	% glycogen	average	stdev
Hunters Point	**none**	1	0.66		
		2	0.44		
		3	0.58		
		4	0.54		
		5	0.31		
		6	0.62	**0.53**	**0.13**
Hunters Point	**sand**	1	0.49		
		2	0.60		
		3	0.47		
		4	0.46		
		5	0.70		
		6	0.56	**0.55**	**0.09**
Hunters Point	**AC_m**	1	0.33		
		2	0.39		
		3	0.38		
		4	0.67		
		5	0.53		
		6	0.57	**0.48**	**0.13**
Hunters Point	**AC_c**	1	0.38		
		2	0.48		
		3	0.44		
		4	0.71		
		5	0.36		
		6	0.50	**0.48**	**0.13**

Matrix	treatment	repl	% glycogen	average	stdev
Richmond	**none**	1	0.41		
		2	0.38		
		3	0.53		
		4	0.41		
		5	0.47		
		6		**0.44**	**0.06**
Richmond	**sand**	1	0.28		
		2	0.43		
		3	0.38		
		4	0.32		
		5	0.36		
		6	0.36	**0.36**	**0.05**
Richmond	**AC_m**	1	0.27		
		2	0.45		
		3	0.20		
		4	0.31		
		5	0.27		
		6	0.35	**0.31**	**0.09**
Richmond	**AC_c**	1	0.35		
		2	0.25		
		3	0.42		
		4	0.29		
		5	0.34		
		6	0.41	**0.34**	**0.07**

by wet weight of the individual organism

Table C14. Numerical data for Figure 37: Lipid, protein and glycogen content for individual worms after exposure to sand. N = 3-6.

Matrix	time	repl	% lipid	average	stdev	% protein	average	stdev	% glycogen	average	stdev
Sand	**Day 4**	1	0.56			3.18			0.79		
		2	0.80			3.78			0.57		
		3	0.76	**0.71**	**0.13**	3.21	**3.39**	**0.34**	0.34	**0.57**	**0.22**
Sand	**Day 11**	1	0.69			2.78			0.70		
		2	0.65			2.27			0.14		
		3	0.00	**0.45**	**0.39**	3.29	**2.78**	**0.51**	1.31	**0.72**	**0.59**
Sand	**day 21**	1	0.44			2.57			0.27		
		2	0.54			1.69			0.16		
		3	0.54	**0.51**	**0.06**	3.58	**2.61**	**0.94**	0.06	**0.16**	**0.11**
Sand	**Day 28**	1	0.54			1.85			0.11		
		2	0.53			2.70			0.18		
		3	0.35	**0.47**	**0.11**	2.13	**2.23**	**0.43**	0.18	**0.16**	**0.04**
Sand with feeding	**Day 21**	1	0.69			2.85			0.48		
		2	0.97			2.63			0.32		
		3	0.98	**0.88**	**0.17**	1.76	**2.41**	**0.58**	0.77	**0.52**	**0.23**
Sand	**Day 0**	1	1.24			3.79			0.97		
		2	0.89			3.35			1.39		
		3	1.17			3.18			1.81		
		4	0.59						1.86		
		5							1.02		
		6		**0.97**	**0.30**		**3.44**	**0.31**	0.63	**1.28**	**0.49**

Table C15. Numerical data for Figure 38: Lipid, protein and glycogen content for individual worms after exposure to various media. For treatments with AC_m 20% please see TableC13. N = 6.

Matrix	treatment	repl	% lipid	average	stdev
Hunters Point	**AC_m (5%)**	1	0.84		
		2	0.69		
		3	0.84		
		4	0.94		
		5	0.96		
		6	1.12	**0.90**	**0.14**
Hunters Point	**AC_f (5%)**	1	1.29		
		2	0.98		
		3	1.03		
		4	0.98		
		5	0.69		
		6	0.60	**0.93**	**0.25**
Hunters Point with feeding	**none**	1	2.14		
		2	1.61		
		3	2.08		
		4	1.50		
		5	1.98		
		6	1.26	**1.76**	**0.36**
Hunters Point with feeding	**AC_m (20%)**	1	0.74		
		2	0.75		
		3	0.89		
		4	0.79		
		5	0.88		
		6	0.85	**0.82**	**0.07**
Hunters Point with feeding	**AC_m (5%)**	1	1.08		
		2	1.38		
		3	0.92		
		4	1.41		
		5	1.93		
		6	1.14	**1.31**	**0.35**
Hunters Point with feeding	**AC_f (5%)**	1	0.72		
		2	0.94		
		3	1.40		
		4	0.62		
		5	3.08		
		6	1.44	**1.37**	**0.91**

by wet weight of the individual organism

Matrix	treatment	repl	% lipid	average	stdev
Blackwaters	**AC_m (5%)**	1	1.10		
		2	1.06		
		3	0.99		
		4	1.14		
		5	0.76		
		6	0.90	**0.99**	**0.14**
Blackwaters	**AC_f (5%)**	1	0.55		
		2	0.90		
		3	0.83		
		4	0.76		
		5	0.65		
		6	0.76	**0.74**	**0.12**
Blackwaters	**none**	1	1.11		
		2	1.98		
		3	1.22		
		4	1.30		
		5	1.62		
		6	2.89	**1.69**	**0.67**
Blackwaters	**AC_m (20%)**	1	1.62		
		2	1.02		
		3	0.71		
		4	1.63		
		5	1.31		
		6	1.29	**1.26**	**0.36**
Blackwaters	**AC_m (5%)**	1	1.06		
		2	2.48		
		3	2.25		
		4	1.88		
		5	1.24		
		6	2.16	**1.85**	**0.57**
Blackwaters	**AC_f (5%)**	1	1.38		
		2	1.15		
		3	1.16		
		4	1.49		
		5	0.78		
		6	2.33	**1.38**	**0.52**

by wet weight of the individual organism

Matrix	treatment	repl	% protein	average	stdev
Hunters Point	**AC_m (5%)**	1	3.24		
		2	2.81		
		3	3.28		
		4	3.58		
		5	3.68		
		6	3.01	**3.27**	**0.33**
Hunters Point	**AC_f (5%)**	1	4.06		
		2	2.68		
		3	2.96		
		4	2.66		
		5	3.71		
		6	4.09	**3.36**	**0.67**
Hunters Point	**none**	1	5.17		
with feeding		2	4.12		
		3	3.87		
		4	5.16		
		5	3.59		
		6	4.37	**4.38**	**0.66**
Hunters Point	**AC_m (20%)**	1	4.30		
with feeding		2	4.10		
		3	3.97		
		4	4.77		
		5	4.33		
		6	4.04	**4.25**	**0.29**
Hunters Point	**AC_m (5%)**	1	4.65		
with feeding		2	3.97		
		3	5.19		
		4	3.18		
		5	4.16		
		6	3.80	**4.16**	**0.70**
Hunters Point	**AC_f (5%)**	1	4.73		
with feeding		2	3.99		
		3	3.81		
		4	5.62		
		5	4.68		
		6	4.41	**4.54**	**0.65**

by wet weight of the individual organism

Matrix	treatment	repl	% protein	average	stdev
Blackwaters	**AC_m (5%)**	1	3.10		
		2	3.11		
		3	3.21		
		4	2.88		
		5	2.70		
		6	3.16	**3.03**	**0.19**
Blackwaters	**AC_f (5%)**	1	3.96		
		2	3.11		
		3	3.17		
		4	3.62		
		5	3.61		
		6	3.17	**3.44**	**0.34**
Blackwaters	**none**	1	3.70		
		2	4.04		
		3	4.22		
		4	4.40		
		5	4.68		
		6	4.81	**4.31**	**0.41**
Blackwaters	**AC_m (20%)**	1	4.14		
		2	4.46		
		3	3.65		
		4	3.93		
		5	4.01		
		6	3.82	**4.00**	**0.28**
Blackwaters	**AC_m (5%)**	1	4.88		
		2	3.86		
		3	4.39		
		4	5.10		
		5	4.59		
		6	5.66	**4.75**	**0.62**
Blackwaters	**AC_f (5%)**	1	4.78		
		2	4.34		
		3	3.66		
		4	3.77		
		5	6.37		
		6	4.53	**4.57**	**0.98**

by wet weight of the individual organism

Matrix	treatment	repl	% glycogen	average	stdev
Hunters Point	**AC_m (5%)**	1	0.52		
		2	0.37		
		3	0.22		
		4	0.37		
		5	0.29		
		6	0.62	**0.40**	**0.15**
Hunters Point	**AC_f (5%)**	1	0.45		
		2	0.33		
		3	0.21		
		4	0.29		
		5	0.35		
		6	0.24	**0.31**	**0.09**
Hunters Point with feeding	**none**	1	0.63		
		2	0.65		
		3	1.10		
		4	0.83		
		5	1.02		
		6	1.30	**0.92**	**0.27**
Hunters Point with feeding	**AC_m (20%)**	1	0.65		
		2	0.76		
		3	0.75		
		4	1.33		
		5	1.04		
		6	1.06	**0.93**	**0.26**
Hunters Point with feeding	**AC_m (5%)**	1	0.92		
		2	0.79		
		3	0.88		
		4	0.99		
		5	0.83		
		6	1.00	**0.90**	**0.08**
Hunters Point with feeding	**AC_f (5%)**	1	0.47		
		2	0.67		
		3	0.68		
		4	0.77		
		5	0.90		
		6	0.62	**0.69**	**0.14**

by wet weight of the individual organism

Matrix	treatment	repl	% glycogen	average	stdev
Blackwaters	**AC_m (5%)**	1	0.40		
		2	0.51		
		3	0.54		
		4	0.48		
		5	0.32		
		6	0.46	**0.45**	**0.08**
Blackwaters	**AC_f (5%)**	1	0.51		
		2	0.33		
		3	0.30		
		4	0.39		
		5	0.41		
		6	0.47	**0.40**	**0.08**
Blackwaters	**none**	1	1.04		
		2	1.03		
		3	0.91		
		4	1.14		
		5	0.82		
		6	0.96	**0.98**	**0.11**
Blackwaters	**AC_m (20%)**	1	1.36		
		2	1.03		
		3	0.81		
		4	0.66		
		5	0.90		
		6	1.20	**0.99**	**0.26**
Blackwaters	**AC_m (5%)**	1	0.67		
		2	0.94		
		3	0.65		
		4	0.60		
		5	0.80		
		6	0.74	**0.73**	**0.12**
Blackwaters	**AC_f (5%)**	1	1.20		
		2	1.03		
		3	0.75		
		4	0.93		
		5	1.28		
		6	1.30	**1.08**	**0.22**

by wet weight of the individual organism

Appendix D. Raw Data Report

1. Mass transfer modeling and long-term effectiveness (Task 6)

Test Title	Sediment PCB determination				
Sample Sets	Sediment PCB determination				
Sample name	Hunters Point sediment				
	Average (n=3)	Stdev		Average (n=3)	Stdev
PCB concentrations (ng PCB/g sed)					
PCB1	ND	ND	PCB136	1.37E+01	2.18E+00
PCB3	ND	ND	PCB110	1.83E+01	4.21E+00
PCB4+10	ND	ND	PCB77	ND	ND
PCB7+9	ND	ND	PCB82	ND	ND
PCB6	ND	ND	PCB151	2.72E+01	4.35E+00
PCB8+5	ND	ND	PCB135	1.25E+01	1.66E+00
PCB12+13	ND	ND	PCB144+124+147	7.64E+00	1.21E+00
PCB18	ND	ND	PCB107	5.01E-01	1.02E-01
PCB15+17	5.59E-01	1.17E-01	PCB123+149	5.98E+01	9.43E+00
PCB24	ND	ND	PCB118	1.01E+01	1.49E+00
PCB27	ND	ND	PCB134	2.53E+00	3.01E-01
PCB16	ND	ND	PCB114+131	1.85E+00	
PCB32	1.63E-01		PCB146	1.40E+01	2.04E+00
PCB26	ND	ND	PCB153	7.87E+01	1.31E+01
PCB25	ND	ND	PCB105	3.49E+00	8.16E-01
PCB31+28	ND	ND	PCB132	1.86E+00	3.89E-01
PCB21+33+53	9.03E-01	1.08E-01	PCB141	1.99E+01	3.32E+00
PCB51	1.17E+00	8.77E-01	PCB137+176+130	1.20E+01	9.94E+00
PCB22	ND	ND	PCB163	4.48E+01	2.41E+01
PCB45	ND	ND	PCB138	7.48E+01	1.29E+01
PCB46	ND	ND	PCB158	1.08E+01	1.87E+00
PCB52+49	5.36E+00	2.85E+00	PCB178	1.66E+01	3.96E+00
PCB43	1.77E+00	4.84E-01	PCB187+182	5.00E+01	1.36E+01
PCB47+48	ND	ND	PCB183	3.28E+01	8.96E+00
PCB44	1.57E+00	1.25E+00	PCB128	4.96E+00	8.53E-01
PCB37	ND	ND	PCB185	5.61E+00	1.91E+00
PCB42	2.39E-01	0.00E+00	PCB174	5.06E+01	1.41E+01
PCB41	3.33E-01	2.95E-02	PCB177	3.36E+01	8.28E+00
PCB71	ND	ND	PCB202	3.57E+00	1.38E+00
PCB64	2.80E-01	1.83E-01	PCB171	9.62E+00	2.25E+00
PCB40	ND	ND	PCB156	3.46E+00	6.70E-01
PCB100	ND	ND	PCB157+200	4.92E+00	1.56E+00
PCB63	ND	ND	PCB172	1.45E+01	3.63E+00
PCB74	ND	ND	PCB197	1.46E+00	
PCB70+76	1.31E+00	5.50E-01	PCB180	1.23E+02	3.70E+01
PCB66+95	2.17E+01	#DIV/0!	PCB191	3.40E+00	7.95E-01
PCB91	2.12E+00	1.38E+00	PCB199	4.13E+00	1.74E+00
PCB56	ND	ND	PCB170+190	5.30E+01	1.39E+01
PCB60	ND	ND	PCB198	2.45E+00	2.26E+00
PCB92+84	5.19E+00	2.73E+00	PCB201	4.85E+01	2.63E+01
PCB89	5.39E-01	2.06E-01	PCB203+196	5.72E+01	2.51E+01
PCB101	2.73E+01	3.39E+00	PCB189	1.95E+00	4.04E-01
PCB99	7.32E+00	1.89E+00	PCB208	8.47E-01	5.35E-01
PCB119	5.25E-01	3.77E-02	PCB195	1.11E+01	4.26E+00
PCB83	4.82E-01	2.23E-01	PCB207	9.97E-01	5.67E-01
PCB97	1.82E+00	6.81E-01	PCB194	2.92E+01	1.16E+01
PCB81	6.13E-01	0.00E+00	PCB205	1.91E+00	7.33E-01
PCB87	8.28E+00	5.37E+00	PCB206	8.12E+00	5.21E+00
PCB85	5.40E+00	1.06E+00	PCB209	1.08E+00	4.70E-01
			Total PCBs	**1.09E+03**	**2.57E+02**

Test Title	PE preloading test				
Sample Sets	PE preloading test				
Sample name	Preloaded PE, 20 week contact				
	Average (n=3)	Stdev		Average (n=3)	Stdev
PCB concentrations (ng PCB/g PE)			**PCB concentrations (ng PCB/g PE)**		
PCB1	ND	ND	PCB136	8.68E+02	6.28E+01
PCB3	ND	ND	PCB110	9.06E+02	8.89E+01
PCB4+10	ND	ND	PCB77	4.52E-01	5.08E-02
PCB7+9	ND	ND	PCB82	ND	ND
PCB6	ND	ND	PCB151	1.98E+03	1.36E+02
PCB8+5	ND	ND	PCB135	9.21E+02	5.35E+01
PCB12+13	ND	ND	PCB144+124+147	6.08E+02	3.93E+01
PCB18	ND	ND	PCB107	1.75E+01	2.43E+00
PCB15+17	4.46E+00	3.13E-01	PCB123+149	4.04E+03	2.60E+02
PCB24	ND	ND	PCB118	5.51E+02	8.27E+01
PCB27	1.45E+01	1.00E+00	PCB134	2.10E+02	3.39E+01
PCB16	ND	ND	PCB114+131	ND	ND
PCB32	2.70E+00	1.81E-01	PCB146	1.12E+03	9.48E+01
PCB26	ND	ND	PCB153	5.92E+03	6.03E+02
PCB25	ND	ND	PCB105	2.18E+02	2.66E+01
PCB31+28	ND	ND	PCB132	3.77E+01	9.37E-01
PCB21+33+53	2.32E+01	2.00E-01	PCB141	1.11E+03	4.73E+01
PCB51	2.74E+01	3.54E+00	PCB137+176+130	4.49E+02	4.27E+01
PCB22	3.21E+00	3.63E-01	PCB163	2.22E+03	1.49E+02
PCB45	ND	ND	PCB138	4.66E+03	3.05E+02
PCB46	ND	ND	PCB158	7.07E+02	5.69E+01
PCB52+49	1.08E+02	2.97E+00	PCB178	1.02E+03	1.45E+02
PCB43	5.33E+01	1.27E+00	PCB187+182	2.85E+03	4.69E+02
PCB47+48	ND	ND	PCB183	1.86E+03	3.43E+02
PCB44	1.98E+01	5.20E-01	PCB128	2.62E+02	1.28E+01
PCB37	2.74E+00	4.17E-01	PCB185	2.79E+02	4.39E+01
PCB42	4.91E+00	1.95E-01	PCB174	2.48E+03	3.04E+02
PCB41	1.17E+01	3.26E+00	PCB177	1.75E+03	2.40E+02
PCB71	ND	ND	PCB202	1.13E+02	5.46E+01
PCB64	6.90E+00	1.18E-01	PCB171	4.98E+02	7.27E+01
PCB40	ND	ND	PCB156	2.01E+02	1.79E+01
PCB100	1.73E+00	4.28E-01	PCB157+200	1.67E+02	1.06E+02
PCB63	ND	ND	PCB172	7.66E+02	1.46E+02
PCB74	1.02E+01	8.38E-01	PCB197	4.91E+01	1.46E+01
PCB70+76	2.32E+01	7.30E-01	PCB180	5.66E+03	1.14E+03
PCB66+95	1.31E+03	9.01E+01	PCB191	1.83E+02	3.45E+01
PCB91	5.86E+01	2.40E+01	PCB199	3.64E+02	3.90E+02
PCB56	3.35E+00	2.87E-01	PCB170+190	2.19E+03	3.59E+02
PCB60	ND	ND	PCB198	1.23E+02	1.32E+02
PCB92+84	9.53E+01	4.30E+00	PCB201	1.23E+03	3.49E+02
PCB89	2.73E+01	3.91E+00	PCB203+196	1.53E+03	4.67E+02
PCB101	2.07E+03	1.95E+02	PCB189	8.35E+01	1.79E+01
PCB99	3.88E+02	4.10E+01	PCB208	7.01E+00	2.97E+00
PCB119	3.77E+01	3.65E+00	PCB195	2.79E+02	7.91E+01
PCB83	1.14E+01	1.09E+00	PCB207	1.06E+01	7.96E+00
PCB97	4.76E+01	1.41E+00	PCB194	6.59E+02	2.10E+02
PCB81	1.91E+01	3.34E-01	PCB205	4.30E+01	1.35E+01
PCB87	2.35E+02	3.25E+01	PCB206	6.87E+01	5.01E+01
PCB85	2.40E+02	3.40E+01	PCB209	6.18E+00	3.09E+00
			Total PCBs	**5.61E+04**	**4.89E+03**

Test Title	14-day aqueous equilibrium test			
Sample Sets	14-day aqueous equilibrium test			
Sample name	14-day-equilibrated water		14-day-equilibrated sediment	
	Average (n=3)	Stdev	Average (n=3)	Stdev
PCB concentrations	**(ng PCB/g sed)**		**(ng PCB/L water)**	
PCB1	ND	ND	ND	ND
PCB3	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND
PCB6	8.01E-01	2.53E-01	ND	ND
PCB8+5	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND
PCB18	ND	ND	ND	ND
PCB15+17	ND	ND	ND	ND
PCB24	ND	ND	ND	ND
PCB27	8.51E-02	5.95E-04	ND	ND
PCB16	ND	ND	ND	ND
PCB32	ND	ND	ND	ND
PCB26	ND	ND	ND	ND
PCB25	3.36E-01	1.36E-01	9.58E-01	5.99E-01
PCB31+28	ND	ND	ND	ND
PCB21+33+53	ND	ND	ND	ND
PCB51	1.03E-01	1.61E-02	7.87E-01	8.82E-03
PCB22	ND	ND	ND	ND
PCB45	ND	ND	ND	ND
PCB46	ND	ND	ND	ND
PCB52+49	6.10E-01	7.43E-02	4.51E+00	6.59E-01
PCB43	2.16E-01	7.67E-02	1.54E+00	2.66E-01
PCB47+48	ND	ND	ND	ND
PCB44	ND	ND	ND	ND
PCB37	ND	ND	ND	ND
PCB42	ND	ND	ND	ND
PCB41	ND	ND	ND	ND
PCB71	ND	ND	ND	ND
PCB64	ND	ND	ND	ND
PCB40	ND	ND	ND	ND
PCB100	ND	ND	ND	ND
PCB63	ND	ND	ND	ND
PCB74	ND	ND	ND	ND
PCB70+76	ND	ND	ND	ND
PCB66+95	ND	ND	ND	ND
PCB91	ND	ND	ND	ND
PCB56	ND	ND	ND	ND
PCB60	ND	ND	ND	ND
PCB92+84	2.55E-01	3.77E-02	5.40E+00	6.44E-01
PCB89	ND	ND	ND	ND
PCB101	9.19E-01	1.73E-01	3.48E+01	7.25E+00
PCB99	1.78E-01	9.55E-03	6.30E+00	5.70E-01
PCB119	ND	ND	ND	ND
PCB83	ND	ND	ND	ND
PCB97	4.51E-02	6.84E-03	1.75E+00	2.35E-01
PCB81	ND	ND	ND	ND
PCB87	1.07E-01	3.11E-02	5.12E+00	1.12E+00
PCB85	1.59E-01	7.17E-03	5.92E+00	9.65E-01
PCB136	3.27E-01	6.60E-02	1.79E+01	3.50E+00
PCB110	5.28E-01	8.57E-02	2.14E+01	4.46E+00
PCB77	ND	ND	ND	ND

PCB82	ND	ND	ND	ND
PCB151	4.53E-01	6.40E-02	3.10E+01	6.35E+00
PCB135	2.36E-01	3.16E-02	1.53E+01	2.62E+00
PCB144+124+147	1.20E-01	1.86E-02	9.22E+00	1.95E+00
PCB107	ND	ND	ND	ND
PCB123+149	1.01E+00	1.27E-01	6.96E+01	1.24E+01
PCB118	1.14E-01	4.29E-02	1.02E+01	1.84E+00
PCB134	3.94E-02	1.64E-03	3.15E+00	5.89E-01
PCB114+131	ND	ND	ND	ND
PCB146	1.79E-01	1.26E-02	1.63E+01	2.10E+00
PCB153	9.44E-01	1.24E-01	8.68E+01	1.38E+01
PCB105	6.30E-02	1.26E-02	4.70E+00	7.88E-01
PCB132	ND	ND	ND	ND
PCB141	1.07E-01	2.05E-02	2.00E+01	6.72E+00
PCB137+176+130	ND	ND	ND	ND
PCB163	4.32E-01	5.26E-02	3.82E+01	5.64E+00
PCB138	9.48E-01	1.02E-01	8.47E+01	1.24E+01
PCB158	1.28E-01	2.19E-02	1.24E+01	1.69E+00
PCB178	1.34E-01	3.10E-02	1.62E+01	2.11E+00
PCB187+182	3.00E-01	1.32E-01	4.65E+01	6.05E+00
PCB183	1.88E-01	7.54E-02	3.09E+01	4.09E+00
PCB128	6.29E-02	1.64E-03	6.15E+00	1.06E+00
PCB185	ND	ND	ND	ND
PCB174	2.99E-01	9.55E-02	4.85E+01	6.42E+00
PCB177	2.15E-01	4.83E-02	3.39E+01	4.30E+00
PCB202	4.04E-02	1.22E-02	2.67E+00	5.00E-01
PCB171	7.88E-02	1.85E-02	9.37E+00	1.27E+00
PCB156	3.80E-02	2.83E-03	4.15E+00	6.84E-01
PCB157+200	ND	ND	ND	ND
PCB172	1.90E-01	5.88E-02	1.46E+01	1.65E+00
PCB197	ND	ND	ND	ND
PCB180	7.31E-01	4.08E-01	1.11E+02	1.39E+01
PCB191	ND	ND	ND	ND
PCB199	4.35E-02	1.17E-02	3.12E+00	3.77E-01
PCB170+190	3.14E-01	9.87E-02	5.20E+01	6.53E+00
PCB198	ND	ND	ND	ND
PCB201	ND	ND	ND	ND
PCB203+196	ND	ND	ND	ND
PCB189	ND	ND	ND	ND
PCB208	ND	ND	ND	ND
PCB195	ND	ND	ND	ND
PCB207	ND	ND	ND	ND
PCB194	ND	ND	ND	ND
PCB205	ND	ND	ND	ND
PCB206	ND	ND	ND	ND
PCB209	ND	ND	ND	ND
Total PCBs	**1.30E+01**	**3.05E+00**	**9.14E+02**	**6.69E+01**

Test Title	Kpe determination					
Sample Sets	Kpe determination in deionized water					
Sample name	Polyethylene			Water		
Replicate number	#1	#2	#3	#1	#2	#3
PCB concentrations	**(ng PCB/g PE)**			**(ng PCB/L water)**		
PCB1	2.05E+02	2.55E+02	2.46E+02	2.71E+01	3.33E+01	3.43E+01
PCB3	2.83E+02	3.37E+02	3.80E+02	1.84E+01	2.12E+01	2.17E+01
PCB4+10	1.36E+02	1.80E+02	1.67E+02	1.01E+01	1.21E+01	1.23E+01
PCB7+9	1.51E+02	1.72E+02	1.63E+02	4.02E+00	4.34E+00	4.65E+00
PCB6	3.04E+02	3.17E+02	3.04E+02	1.11E+01	1.19E+01	1.32E+01
PCB8+5	1.90E+03	2.11E+03	2.02E+03	4.67E+01	5.06E+01	5.44E+01
PCB12+13	3.03E+01	3.20E+01	3.26E+01	5.58E-01	6.46E-01	6.64E-01
PCB18	6.93E+02	7.50E+02	7.29E+02	9.84E+00	1.03E+01	1.14E+01
PCB15+17	7.92E+02	8.31E+02	8.20E+02	8.60E+00	9.01E+00	9.86E+00
PCB24	7.67E+00	8.89E+00	7.92E+00	1.12E-01	1.15E-01	1.24E-01
PCB27	3.90E+01	4.24E+01	4.10E+01	5.37E-01	5.68E-01	6.19E-01
PCB16	3.06E+02	3.48E+02	3.35E+02	5.81E+00	6.43E+00	6.77E+00
PCB32	4.01E+02	4.29E+02	4.19E+02	4.62E+00	4.80E+00	5.26E+00
PCB26	1.68E+02	1.71E+02	1.71E+02	1.06E+00	1.12E+00	1.28E+00
PCB25	9.47E+01	9.04E+01	9.30E+01	1.16E+00	1.11E+00	8.96E-01
PCB31+28	2.56E+03	2.62E+03	2.61E+03	1.37E+01	1.40E+01	1.51E+01
PCB21+33+53	1.02E+03	1.05E+03	1.04E+03	6.88E+00	7.02E+00	7.66E+00
PCB51	5.28E+01	5.20E+01	5.26E+01	2.34E-01	2.14E-01	2.39E-01
PCB22	6.95E+02	7.28E+02	7.13E+02	5.01E+00	5.16E+00	5.63E+00
PCB45	2.14E+02	2.27E+02	2.23E+02	1.40E+00	1.46E+00	1.57E+00
PCB46	8.33E+01	8.79E+01	8.68E+01	6.46E-01	6.68E-01	7.14E-01
PCB52+49	1.41E+03	1.42E+03	1.43E+03	5.07E+00	5.01E+00	5.61E+00
PCB43	6.93E+02	6.90E+02	6.97E+02	1.92E+00	1.91E+00	2.07E+00
PCB47+48	6.38E+02	6.35E+02	6.46E+02	1.48E+00	1.59E+00	1.65E+00
PCB44	1.20E+03	1.24E+03	1.23E+03	5.03E+00	5.08E+00	5.61E+00
PCB37	3.38E+02	3.41E+02	3.43E+02	1.18E+00	1.23E+00	1.35E+00
PCB42	4.26E+02	4.25E+02	4.27E+02	1.86E+00	1.86E+00	2.10E+00
PCB41	1.92E+02	1.94E+02	1.94E+02	6.23E-01	6.26E-01	6.94E-01
PCB71	4.61E+02	4.72E+02	4.72E+02	1.66E+00	1.69E+00	1.85E+00
PCB64	5.47E+02	5.49E+02	5.53E+02	1.54E+00	1.55E+00	1.70E+00
PCB40	2.20E+02	2.49E+02	2.53E+02	1.42E+00	1.39E+00	1.52E+00
PCB100	2.81E+01	2.91E+01	2.99E+01	3.99E-02	4.07E-02	3.77E-02
PCB63	5.82E+01	5.69E+01	5.82E+01	8.94E-02	1.04E-01	1.02E-01
PCB74	6.35E+02	6.02E+02	6.05E+02	1.79E+00	1.16E+00	1.63E+00
PCB70+76	1.06E+03	1.05E+03	1.06E+03	1.73E+00	1.83E+00	1.95E+00
PCB66+95	1.97E+03	1.98E+03	2.45E+03	2.29E+00	2.49E+00	2.49E+00
PCB91	1.54E+02	1.34E+02	1.53E+02	1.52E-01	1.66E-01	1.73E-01
PCB56	5.47E+02	5.39E+02	5.46E+02	1.12E+00	1.22E+00	1.20E+00
PCB60	3.67E+02	3.71E+02	3.82E+02	5.82E-01	6.29E-01	6.12E-01
PCB92+84	4.92E+02	4.89E+02	4.97E+02	7.75E-01	8.20E-01	8.33E-01
PCB89	2.35E+01	2.21E+01	2.32E+01	1.92E-02	1.91E-02	1.96E-02
PCB101	5.46E+02	5.13E+02	5.19E+02	3.28E-01	3.49E-01	3.38E-01
PCB99	2.28E+02	2.12E+02	2.13E+02	1.37E-01	1.51E-01	1.44E-01
PCB119	7.83E+00	7.00E+00	7.36E+00	1.05E-02	7.89E-03	7.81E-03
PCB83	4.03E+01	3.74E+01	3.85E+01	3.78E-02	3.98E-02	3.80E-02
PCB97	1.63E+02	1.54E+02	1.57E+02	1.22E-01	1.34E-01	1.25E-01
PCB81	4.25E+01	3.87E+01	3.88E+01	4.96E-02	4.19E-02	4.45E-02
PCB87	2.93E+02	2.76E+02	2.81E+02	2.36E-01	2.39E-01	2.36E-01
PCB85	2.10E+02	1.96E+02	1.99E+02	1.27E-01	1.28E-01	1.23E-01
PCB136	2.20E+02	2.07E+02	2.10E+02	1.25E-01	1.26E-01	1.21E-01
PCB110	5.69E+02	5.40E+02	5.47E+02	4.57E-01	4.82E-01	4.69E-01
PCB77	5.09E+01	4.95E+01	4.96E+01	7.09E-02	7.68E-02	7.46E-02

PCB82	1.15E+02	1.10E+02	1.15E+02	1.39E-01	1.36E-01	1.38E-01
PCB151	5.57E+02	5.16E+02	5.06E+02	1.64E-01	1.61E-01	1.49E-01
PCB135	1.57E+02	1.45E+02	1.44E+02	5.47E-02	5.36E-02	5.12E-02
PCB144+124+147	1.14E+02	1.05E+02	1.04E+02	3.05E-02	2.81E-02	2.54E-02
PCB107	3.49E+01	3.25E+01	3.15E+01	3.94E-02	2.12E-02	1.85E-02
PCB123+149	9.01E+02	8.29E+02	8.18E+02	2.54E-01	2.71E-01	2.58E-01
PCB118	3.79E+02	3.48E+02	3.44E+02	1.35E-01	1.43E-01	1.31E-01
PCB134	2.43E+01	1.87E+01	2.23E+01	7.63E-03	6.60E-03	5.07E-03
PCB114+131	3.33E+01	3.15E+01	3.07E+01	2.03E-02	2.05E-02	1.88E-02
PCB146	1.20E+02	1.09E+02	1.03E+02	1.62E-02	1.94E-02	1.62E-02
PCB153	9.37E+02	8.67E+02	7.84E+02	1.24E-01	1.47E-01	1.26E-01
PCB105	3.24E+01	2.81E+01	3.53E+01	1.07E-02	1.24E-02	1.16E-02
PCB132	2.00E+02	1.79E+02	1.83E+02	8.86E-02	1.03E-01	8.68E-02
PCB141	6.06E+02	5.44E+02	5.42E+02	6.00E-02	7.00E-02	5.58E-02
PCB137+176+130	1.08E+02	9.85E+01	9.35E+01	9.48E-03	1.22E-02	9.78E-03
PCB163	3.29E+02	3.00E+02	2.88E+02	7.17E-02	7.76E-02	6.81E-02
PCB138	5.69E+02	5.23E+02	4.99E+02	1.15E-01	1.23E-01	1.14E-01
PCB158	8.71E+01	7.78E+01	7.60E+01	1.71E-02	1.72E-02	1.71E-02
PCB178	3.73E+02	3.41E+02	3.15E+02	3.39E-02	3.47E-02	3.69E-02
PCB187+182	1.30E+03	1.21E+03	1.10E+03	8.69E-02	9.93E-02	8.96E-02
PCB183	6.01E+02	5.60E+02	5.02E+02	3.80E-02	4.48E-02	3.83E-02
PCB128	2.95E+01	2.73E+01	2.66E+01	8.83E-03	8.31E-03	7.79E-03
PCB185	1.66E+02	1.53E+02	1.40E+02	1.53E-02	1.61E-02	1.68E-02
PCB174	1.14E+03	1.07E+03	9.89E+02	9.32E-02	1.04E-01	9.53E-02
PCB177	5.90E+02	5.42E+02	5.01E+02	4.23E-02	5.02E-02	4.65E-02
PCB202	1.62E+02	1.50E+02	1.33E+02	1.03E-02	1.06E-02	1.31E-02
PCB171	1.14E+02	1.05E+02	9.68E+01	1.91E-02	1.76E-02	1.78E-02
PCB156	1.88E+01	1.73E+01	1.61E+01	6.27E-03	6.35E-03	7.48E-03
PCB157+200	1.34E+02	1.25E+02	1.11E+02	3.57E-03	3.73E-03	5.38E-03
PCB172	2.07E+02	1.86E+02	1.36E+02	5.59E-02	4.68E-02	5.99E-02
PCB197	3.71E+01	3.40E+01	3.05E+01	6.15E-03	4.23E-03	5.92E-03
PCB180	2.32E+03	2.19E+03	1.90E+03	1.15E-01	1.43E-01	1.47E-01
PCB191	4.25E+01	3.89E+01	3.45E+01	ND	ND	ND
PCB199	1.52E+02	1.44E+02	1.27E+02	2.16E-02	1.91E-02	2.26E-02
PCB170+190	6.24E+02	5.85E+02	5.22E+02	4.65E-02	5.33E-02	5.41E-02
PCB198	4.18E+01	3.99E+01	3.34E+01	ND	ND	ND
PCB201	1.58E+03	1.51E+03	1.27E+03	4.16E-02	4.97E-02	6.52E-02
PCB203+196	1.64E+03	1.58E+03	1.30E+03	4.99E-02	5.57E-02	7.99E-02
PCB189	1.14E+01	1.08E+01	9.25E+00	ND	ND	ND
PCB208	3.43E+01	3.37E+01	2.72E+01	2.62E-03	2.21E-03	3.84E-03
PCB195	2.48E+02	2.36E+02	1.99E+02	8.00E-03	8.83E-03	1.20E-02
PCB207	3.18E+01	3.10E+01	2.51E+01	4.11E-03	3.44E-03	4.26E-03
PCB194	6.87E+02	6.68E+02	5.32E+02	2.03E-02	2.11E-02	3.48E-02
PCB205	3.93E+01	3.77E+01	3.05E+01	2.28E-03	1.40E-03	2.67E-03
PCB206	2.56E+02	2.53E+02	1.94E+02	5.15E-03	4.67E-03	1.13E-02
PCB209	4.25E+00	4.33E+00	3.23E+00	ND	ND	ND
PCB29	2.33E+02	2.37E+02	2.32E+02	1.31E+00	1.35E+00	1.43E+00
PCB69	2.78E+02	2.76E+02	2.78E+02	6.07E-01	6.07E-01	6.81E-01
PCB103	3.19E+02	3.00E+02	2.96E+02	1.29E-01	2.04E-01	1.49E-01
PCB155	2.96E+02	2.75E+02	2.70E+02	5.53E-02	9.05E-02	9.42E-02
PCB192	3.26E+02	3.11E+02	2.87E+02	2.22E-02	2.57E-02	2.61E-02

Test Title	Kpe determination					
Sample Sets	Kpe determination in 30 ppt saltwater					
Sample name	Polyethylene			Water		
Replicate number	#1	#2	#3	#1	#2	#3
PCB concentrations	**(ng PCB/g PE)**			**(ng PCB/L water)**		
PCB1	2.86E+02	3.16E+02	3.20E+02	2.82E+01	3.07E+01	2.73E+01
PCB3	3.64E+02	3.90E+02	4.45E+02	1.69E+01	1.76E+01	1.57E+01
PCB4+10	1.91E+02	2.01E+02	2.19E+02	9.44E+00	1.01E+01	8.89E+00
PCB7+9	1.82E+02	1.72E+02	2.07E+02	3.31E+00	3.31E+00	2.85E+00
PCB6	3.61E+02	3.43E+02	3.84E+02	1.07E+01	1.11E+01	9.31E+00
PCB8+5	2.24E+03	2.25E+03	2.46E+03	3.82E+01	3.83E+01	3.37E+01
PCB12+13	3.30E+01	3.51E+01	3.81E+01	4.62E-01	4.47E-01	4.17E-01
PCB18	7.92E+02	7.72E+02	8.50E+02	7.83E+00	7.70E+00	6.62E+00
PCB15+17	8.82E+02	8.54E+02	9.28E+02	6.83E+00	6.60E+00	5.78E+00
PCB24	8.65E+00	8.53E+00	9.60E+00	8.62E-02	8.39E-02	7.40E-02
PCB27	4.47E+01	4.48E+01	4.85E+01	4.37E-01	5.61E-01	3.77E-01
PCB16	3.58E+02	3.50E+02	3.85E+02	4.80E+00	4.81E+00	4.33E+00
PCB32	4.50E+02	4.38E+02	4.75E+02	3.66E+00	3.53E+00	3.13E+00
PCB26	1.79E+02	1.75E+02	1.91E+02	8.29E-01	8.34E-01	7.47E-01
PCB25	9.75E+01	9.07E+01	1.00E+02	8.35E-01	7.87E-01	6.06E-01
PCB31+28	2.71E+03	2.66E+03	2.84E+03	1.06E+01	1.03E+01	9.15E+00
PCB21+33+53	1.10E+03	1.06E+03	1.16E+03	5.46E+00	5.32E+00	4.72E+00
PCB51	5.53E+01	5.16E+01	5.60E+01	1.76E-01	2.32E-01	1.53E-01
PCB22	7.55E+02	7.34E+02	8.06E+02	3.99E+00	3.89E+00	3.48E+00
PCB45	2.32E+02	2.19E+02	2.45E+02	1.18E+00	1.13E+00	1.00E+00
PCB46	9.03E+01	8.53E+01	9.47E+01	5.42E-01	5.11E-01	4.71E-01
PCB52+49	1.47E+03	1.41E+03	1.53E+03	4.26E+00	4.04E+00	3.57E+00
PCB43	7.19E+02	6.85E+02	7.43E+02	1.60E+00	1.56E+00	1.39E+00
PCB47+48	6.55E+02	6.26E+02	6.75E+02	1.29E+00	1.23E+00	1.06E+00
PCB44	1.28E+03	1.22E+03	1.36E+03	4.28E+00	4.07E+00	3.74E+00
PCB37	3.56E+02	3.41E+02	3.72E+02	1.00E+00	9.61E-01	8.87E-01
PCB42	4.46E+02	4.18E+02	4.65E+02	1.71E+00	1.53E+00	1.50E+00
PCB41	2.01E+02	1.92E+02	2.10E+02	5.55E-01	5.02E-01	4.72E-01
PCB71	4.92E+02	4.57E+02	5.16E+02	1.45E+00	1.32E+00	1.28E+00
PCB64	5.71E+02	5.43E+02	5.98E+02	1.36E+00	1.24E+00	1.17E+00
PCB40	2.42E+02	2.39E+02	2.69E+02	1.21E+00	1.16E+00	1.26E+00
PCB100	3.08E+01	2.92E+01	3.20E+01	3.25E-02	3.06E-02	2.95E-02
PCB63	5.85E+01	5.81E+01	6.24E+01	8.20E-02	8.68E-02	8.72E-02
PCB74	6.17E+02	6.11E+02	6.40E+02	9.51E-01	6.44E+00	7.71E-01
PCB70+76	1.07E+03	1.05E+03	1.14E+03	1.68E+00	1.57E+00	1.45E+00
PCB66+95	2.52E+03	2.41E+03	2.63E+03	2.20E+00	2.12E+00	1.88E+00
PCB91	1.54E+02	1.46E+02	1.61E+02	1.88E-01	1.84E-01	1.64E-01
PCB56	5.53E+02	5.51E+02	6.03E+02	1.10E+00	1.14E+00	1.01E+00
PCB60	3.81E+02	3.66E+02	4.09E+02	5.56E-01	5.35E-01	5.11E-01
PCB92+84	5.04E+02	4.73E+02	5.33E+02	8.46E-01	8.37E-01	7.58E-01
PCB89	2.80E+01	2.67E+01	2.93E+01	2.22E-02	2.34E-02	1.92E-02
PCB101	5.30E+02	5.14E+02	5.57E+02	3.82E-01	4.53E-01	3.26E-01
PCB99	2.18E+02	2.11E+02	2.30E+02	1.66E-01	1.87E-01	1.41E-01
PCB119	7.67E+00	7.34E+00	7.92E+00	7.05E-03	1.03E-02	7.37E-03
PCB83	3.96E+01	3.77E+01	4.16E+01	5.23E-02	5.05E-02	3.96E-02
PCB97	1.60E+02	1.54E+02	1.69E+02	1.51E-01	1.62E-01	1.29E-01
PCB81	4.09E+01	3.97E+01	4.19E+01	4.15E-02	5.53E-02	3.87E-02
PCB87	2.86E+02	2.76E+02	3.03E+02	2.78E-01	3.08E-01	2.49E-01
PCB85	2.03E+02	1.96E+02	2.15E+02	1.55E-01	1.83E-01	1.36E-01
PCB136	2.16E+02	2.03E+02	2.27E+02	1.72E-01	2.36E-01	1.45E-01
PCB110	5.58E+02	5.40E+02	5.93E+02	5.67E-01	6.22E-01	5.00E-01
PCB77	4.87E+01	4.79E+01	5.33E+01	6.94E-02	8.14E-02	6.97E-02

PCB82	1.15E+02	1.11E+02	1.26E+02	1.68E-01	1.71E-01	1.51E-01
PCB151	5.28E+02	5.10E+02	5.60E+02	2.12E-01	3.12E-01	1.79E-01
PCB135	1.51E+02	1.67E+02	1.60E+02	8.13E-02	1.06E-01	6.63E-02
PCB144+124+147	1.07E+02	1.04E+02	1.14E+02	4.08E-02	5.89E-02	3.85E-02
PCB107	3.27E+01	3.23E+01	3.55E+01	3.53E-02	3.01E-02	1.61E-02
PCB123+149	8.51E+02	8.24E+02	9.09E+02	3.80E-01	5.89E-01	3.01E-01
PCB118	3.57E+02	3.49E+02	3.81E+02	1.83E-01	2.26E-01	1.47E-01
PCB134	2.47E+01	2.21E+01	2.43E+01	1.27E-02	1.56E-02	9.93E-03
PCB114+131	3.21E+01	3.14E+01	3.36E+01	2.06E-02	2.20E-02	1.88E-02
PCB146	1.10E+02	1.06E+02	1.18E+02	2.44E-02	4.11E-02	2.14E-02
PCB153	8.54E+02	8.10E+02	9.10E+02	1.56E-01	3.69E-01	1.69E-01
PCB105	3.18E+01	3.65E+01	3.73E+01	1.77E-02	2.58E-02	1.58E-02
PCB132	1.88E+02	1.81E+02	2.04E+02	1.26E-01	1.54E-01	1.13E-01
PCB141	5.28E+02	5.22E+02	5.56E+02	9.92E-02	2.95E-01	8.87E-02
PCB137+176+130	1.00E+02	9.60E+01	1.07E+02	1.83E-02	4.84E-02	1.47E-02
PCB163	3.04E+02	2.95E+02	3.28E+02	1.05E-01	1.71E-01	9.19E-02
PCB138	5.30E+02	5.11E+02	5.69E+02	1.79E-01	3.23E-01	1.58E-01
PCB158	7.99E+01	7.76E+01	8.43E+01	2.61E-02	3.81E-02	2.01E-02
PCB178	3.44E+02	3.30E+02	3.63E+02	5.59E-02	1.34E-01	5.21E-02
PCB187+182	1.20E+03	1.16E+03	1.27E+03	1.51E-01	4.42E-01	1.29E-01
PCB183	5.50E+02	5.36E+02	5.84E+02	6.15E-02	2.05E-01	5.78E-02
PCB128	2.75E+01	2.65E+01	2.91E+01	1.54E-02	2.24E-02	1.45E-02
PCB185	1.52E+02	1.48E+02	1.62E+02	2.52E-02	6.28E-02	2.07E-02
PCB174	1.07E+03	1.03E+03	1.14E+03	1.96E-01	5.74E-01	1.66E-01
PCB177	5.47E+02	5.26E+02	5.80E+02	8.80E-02	2.53E-01	7.46E-02
PCB202	1.49E+02	1.43E+02	1.55E+02	1.42E-02	4.84E-02	1.09E-02
PCB171	1.05E+02	1.01E+02	1.11E+02	2.62E-02	5.98E-02	2.03E-02
PCB156	1.73E+01	1.69E+01	1.86E+01	8.67E-03	1.25E-02	6.60E-03
PCB157+200	1.24E+02	1.20E+02	1.30E+02	4.78E-03	4.52E-02	3.95E-03
PCB172	1.72E+02	1.73E+02	1.84E+02	6.37E-02	1.12E-01	4.45E-02
PCB197	3.46E+01	3.31E+01	3.52E+01	6.24E-03	3.99E-03	4.26E-03
PCB180	2.09E+03	2.09E+03	2.23E+03	2.24E-01	7.92E-01	1.88E-01
PCB191	3.81E+01	3.71E+01	3.92E+01	ND	2.03E-02	ND
PCB199	1.41E+02	1.37E+02	1.47E+02	2.97E-02	7.81E-02	2.09E-02
PCB170+190	5.69E+02	5.65E+02	6.03E+02	9.12E-02	2.87E-01	7.77E-02
PCB198	3.81E+01	3.77E+01	3.92E+01	ND	1.14E-02	ND
PCB201	1.43E+03	1.44E+03	1.50E+03	8.73E-02	5.12E-01	7.47E-02
PCB203+196	1.47E+03	1.51E+03	1.55E+03	8.84E-02	5.04E-01	7.21E-02
PCB189	1.02E+01	1.06E+01	1.10E+01	ND	1.09E-02	ND
PCB208	3.10E+01	3.23E+01	3.23E+01	3.23E-03	1.08E-02	2.27E-03
PCB195	2.22E+02	2.27E+02	2.33E+02	1.77E-02	9.85E-02	1.44E-02
PCB207	2.87E+01	2.97E+01	2.96E+01	4.00E-03	1.06E-02	2.96E-03
PCB194	5.92E+02	6.43E+02	6.34E+02	3.84E-02	2.41E-01	3.06E-02
PCB205	3.36E+01	3.63E+01	3.57E+01	2.58E-03	1.27E-02	1.96E-03
PCB206	2.20E+02	2.46E+02	2.34E+02	8.41E-03	7.16E-02	8.58E-03
PCB209	3.62E+00	4.14E+00	3.92E+00	ND	ND	ND
PCB29	2.46E+02	2.41E+02	2.58E+02	9.81E-01	9.51E-01	8.58E-01
PCB69	2.86E+02	2.74E+02	2.96E+02	5.38E-01	4.94E-01	4.29E-01
PCB103	3.24E+02	2.94E+02	3.21E+02	2.44E-01	1.57E-01	1.76E-01
PCB155	2.79E+02	2.67E+02	2.93E+02	1.01E-01	1.04E-01	4.81E-02
PCB192	3.05E+02	2.99E+02	3.22E+02	3.52E-02	9.80E-02	3.06E-02

Test Title	Sediment desorption test					
Sample Sets	Hunters Point sediment desorption test					
Sample name	1 day			2 days		
Replicate number	#1	#2	#3	#1	#2	#3
PCB released (ng PCB/g sed)						
PCB43	2.36E-01	2.64E-01	2.76E-01	4.85E-01	5.80E-01	5.06E-01
PCB101	5.18E+00	4.72E+00	4.19E+00	9.91E+00	9.34E+00	8.27E+00
PCB153	1.22E+01	1.07E+01	1.03E+01	2.25E+01	2.04E+01	2.04E+01
PCB180	1.56E+01	1.41E+01	1.37E+01	2.52E+01	2.35E+01	2.40E+01
PCB199	5.07E-01	4.81E-01	4.53E-01	8.40E-01	8.30E-01	8.20E-01
Sample name	3 days			8 days		
Replicate number	#1	#2	#3	#1	#2	#3
PCB released (ng PCB/g sed)						
PCB43	6.23E-01	6.34E-01	5.35E-01	3.38E-01	4.46E-01	4.89E-01
PCB101	1.10E+01	1.09E+01	8.49E+00	7.35E+00	7.74E+00	6.27E+00
PCB153	2.68E+01	2.60E+01	2.44E+01	1.99E+01	2.02E+01	1.95E+01
PCB180	3.00E+01	2.77E+01	2.76E+01	2.24E+01	2.24E+01	2.37E+01
PCB199	9.72E-01	9.27E-01	8.98E-01	6.81E-01	7.11E-01	7.72E-01
Sample name	16 days			28 days		
Replicate number	#1	#2	#3	#1	#2	#3
PCB released (ng PCB/g sed)						
PCB43	4.73E-01	4.38E-01	5.77E-01	3.88E-01	4.36E-01	5.05E-01
PCB101	8.24E+00	5.65E+00	9.10E+00	7.80E+00	8.09E+00	6.77E+00
PCB153	2.49E+01	1.76E+01	2.50E+01	2.06E+01	2.03E+01	2.04E+01
PCB180	3.09E+01	2.18E+01	3.21E+01	2.25E+01	2.25E+01	2.37E+01
PCB199	9.85E-01	7.04E-01	1.10E+00	6.68E-01	6.86E-01	7.59E-01
Sample name	57 days			PCB residual in sediment		
Replicate number	#1	#2	#3	#1	#2	#3
PCB released (ng PCB/g sed)						
PCB43	5.07E-01	3.61E-01	5.86E-01	8.90E+00	3.52E+00	3.81E+00
PCB101	8.76E+00	5.83E+00	9.90E+00	1.23E+02	6.83E+01	5.53E+01
PCB153	2.67E+01	1.79E+01	2.67E+01	1.76E+02	2.08E+02	1.73E+02
PCB180	3.10E+01	2.18E+01	3.23E+01	1.99E+02	2.88E+02	2.45E+02
PCB199	9.46E-01	6.83E-01	1.07E+00	4.66E+00	8.56E+00	7.56E+00

Test Title	Activated carbon isotherm test					
Sample Sets	6 month contact					
Sample name	<45 μm AC			75-150 μm AC		
Replicate number	#1	#2	#3	#1	#2	#3
Residual PCB concentration in preloaded PE (ng PCB/g PE)						
PCB43	ND	ND	ND	1.41E+00	1.36E+00	1.54E+00
PCB101	3.74E+01	2.76E+01	4.91E+01	2.14E+02	1.28E+02	2.41E+02
PCB153	3.30E+02	4.30E+02	3.57E+02	1.18E+03	1.53E+03	2.03E+03
PCB180	3.57E+02	7.91E+02	3.77E+02	9.26E+02	1.69E+03	2.47E+03
PCB199	9.76E+00	2.17E+01	1.03E+01	2.27E+01	3.62E+01	5.43E+01

Sample Sets	12 month contact					
Sample name	<45 μm AC			75-150 μm AC		
Replicate number	#1	#2	#3	#1	#2	#3
Residual PCB concentration in preloaded PE (ng PCB/g PE)						
PCB43	ND	ND	ND	9.54E-01	ND	ND
PCB101	1.53E+01	2.01E+01	2.19E+01	1.94E+02	1.27E+02	9.44E+01
PCB153	1.86E+02	2.33E+02	4.09E+02	2.10E+03	1.51E+03	1.65E+03
PCB180	2.04E+02	2.81E+02	7.41E+02	1.96E+03	1.40E+03	2.31E+03
PCB199	5.72E+00	8.66E+00	2.02E+01	4.50E+01	3.51E+01	5.67E+01

Test Title	Activated carbon fouling test			
Sample name	<45 μm AC		75-150 μm AC	
	Average (n=3)	Stdev	Average (n=2)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)				
PCB43	3.89E-02	9.42E-03	4.43E-02	1.89E-03
PCB101	7.55E-01	4.40E-02	4.25E+00	5.95E-01
PCB153	3.95E+00	7.15E-01	2.30E+01	6.26E-01
PCB180	6.69E+00	1.22E+00	4.17E+01	2.11E+00
PCB199	5.64E-01	1.25E-01	2.78E+00	2.93E-01

Sample name	control	
	Average (n=2)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)		
PCB43	3.57E+01	9.34E+00
PCB101	1.09E+03	1.30E+02
PCB153	1.91E+03	1.49E+03
PCB180	1.95E+03	2.73E+02
PCB199	2.35E+01	1.97E+00

Sample Sets	6 month contact			
Sample name	<45 μm AC		75-150 μm AC	
Replicate number	Average (n=3)	Stdev	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)				
PCB43	1.15E-02	2.13E-03	1.51E-02	2.78E-03
PCB101	5.14E-01	6.66E-02	6.91E-01	1.86E-01
PCB153	1.03E+00	7.70E-02	1.99E+00	5.31E-01
PCB180	1.61E+00	2.13E-01	3.01E+00	7.56E-01
PCB199	3.10E-01	9.87E-02	4.61E-01	5.54E-02

Sample name	control	
Replicate number	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)		
PCB43	1.82E+01	3.00E+00
PCB101	2.80E+02	4.22E+01
PCB153	4.34E+02	6.73E+01
PCB180	2.60E+02	3.62E+01
PCB199	5.00E+00	6.46E-01

Sample Sets	12 month contact			
Sample name	<45 μm AC		75-150 μm AC	
Replicate number	Average (n=3)	Stdev	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)				
PCB43	8.73E-03	9.48E-04	1.33E-02	2.95E-03
PCB101	5.14E-01	1.41E-01	1.72E+00	2.36E-02
PCB153	1.72E+00	1.85E-01	1.06E+01	2.51E+00
PCB180	2.85E+00	2.32E-01	1.68E+01	6.41E+00
PCB199	3.37E-01	8.75E-02	1.24E+00	3.71E-01

Sample name	control	
Replicate number	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)		
PCB43	1.61E+01	2.02E+00
PCB101	2.92E+02	2.64E+01
PCB153	1.00E+03	1.49E+02
PCB180	9.17E+02	2.40E+02
PCB199	2.16E+01	6.18E+00

Sample Sets	18 month contact			
Sample name	**<45 µm AC**		**75-150 µm AC**	
Replicate number	Average (n=3)	Stdev	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)				
PCB43	1.36E-02	1.67E-03	1.74E-02	1.29E-03
PCB101	4.36E-01	1.39E-01	1.39E+00	2.96E-01
PCB153	1.54E+00	2.55E-01	1.03E+01	3.21E+00
PCB180	2.47E+00	1.31E-01	1.55E+01	4.78E+00
PCB199	3.27E-01	5.64E-02	1.10E+00	2.09E-01

Sample name	**control**	
Replicate number	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)		
PCB43	1.44E+01	2.54E+00
PCB101	2.54E+02	3.59E+01
PCB153	1.02E+03	2.03E+02
PCB180	1.12E+03	2.49E+02
PCB199	2.83E+01	7.15E+00

Sample Sets	24 month contact			
Sample name	**<45 µm AC**		**75-150 µm AC**	
Replicate number	Average (n=3)	Stdev	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)				
PCB43	9.08E-03	1.92E-03	1.28E-02	4.34E-03
PCB101	3.30E-01	5.38E-02	4.72E-01	2.64E-02
PCB153	1.03E+00	4.41E-01	3.03E+00	1.18E+00
PCB180	1.72E+00	8.66E-01	6.88E+00	3.50E+00
PCB199	2.21E-01	5.77E-02	6.01E-01	2.60E-01

Sample name	**control**	
Replicate number	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)		
PCB43	1.19E+01	1.46E+00
PCB101	2.41E+02	2.02E+01
PCB153	7.88E+02	1.70E+02
PCB180	8.48E+02	2.80E+02
PCB199	1.92E+01	6.42E+00

Sample Sets	30 month contact			
Sample name	**<45 µm AC**		**75-150 µm AC**	
Replicate number	Average (n=3)	Stdev	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)				
PCB43	2.64E-02	3.57E-02	9.20E-03	1.41E-03
PCB101	2.29E-01	5.31E-02	6.88E-01	1.75E-01
PCB153	8.18E-01	4.24E-01	1.85E+00	8.51E-01
PCB180	9.25E-01	4.46E-01	2.55E+00	1.31E+00
PCB199	3.40E-02	3.03E-02	1.69E-01	9.42E-02

Sample name	**control**	
Replicate number	Average (n=3)	Stdev
28-day PCB uptake in PE (ng PCB/g PE)		
PCB43	8.27E+00	2.86E-01
PCB101	2.22E+02	1.11E+01
PCB153	7.36E+02	6.49E+01
PCB180	6.76E+02	1.77E+02
PCB199	1.29E+01	4.04E+00

Test Title	Sediment column studies					
Sample Sets	No-Flow, 1 month contact					
Sample name	control		2 min mixing, 75-150 μm AC		30 min mixing, 75-150 μm AC	
	Average (n=2)	Deviation	Average (n=2)	Deviation	Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)						
PCB1	ND	ND	ND	ND	ND	ND
PCB3	ND	ND	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND	ND	ND
PCB6	ND	ND	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND	ND	ND
PCB18	ND	ND	ND	ND	ND	ND
PCB15+17	ND	ND	ND	ND	ND	ND
PCB24	ND	ND	ND	ND	ND	ND
PCB27	6.96E+00		ND	ND	ND	ND
PCB16	ND	ND	ND	ND	ND	ND
PCB32	1.66E+00	6.97E-02	ND	ND	ND	ND
PCB26	ND	ND	ND	ND	ND	ND
PCB25	3.42E+00		5.43E-01		ND	ND
PCB31+28	ND	ND	ND	ND	ND	ND
PCB21+33+53	1.21E+01	9.89E-01	ND	ND	ND	ND
PCB51	1.04E+01	9.20E-01	9.81E-01		ND	ND
PCB22	2.24E+00		ND	ND	ND	ND
PCB45	ND	ND	ND	ND	ND	ND
PCB46	ND	ND	ND	ND	ND	ND
PCB52+49	3.43E+01	3.67E+00	1.73E+00		ND	ND
PCB43	1.62E+01	1.47E+00	9.48E-01		ND	ND
PCB47+48	ND	ND	ND	ND	ND	ND
PCB44	8.94E+00		ND	ND	ND	ND
PCB37	ND	ND	ND	ND	ND	ND
PCB42	2.63E+00	3.44E-01	ND	ND	ND	ND
PCB41	3.66E+00	2.62E-01	ND	ND	ND	ND
PCB71	ND	ND	ND	ND	ND	ND
PCB64	1.99E+00	2.19E-01	ND	ND	ND	ND
PCB40	ND	ND	ND	ND	ND	ND
PCB100	ND	ND	ND	ND	ND	ND
PCB63	ND	ND	ND	ND	ND	ND
PCB74	ND	ND	ND	ND	ND	ND
PCB70+76	6.34E+00	4.50E-01	ND	ND	ND	ND
PCB66+95	1.97E+02		ND	ND	ND	ND
PCB91	1.08E+01	9.47E-01	1.80E+00	1.90E-01	7.40E-01	
PCB56	2.73E+00	2.90E-01	ND	ND	ND	ND
PCB60	ND	ND	ND	ND	ND	ND
PCB92+84	4.03E+01	3.39E+00	3.89E+00	4.09E-01	ND	ND
PCB89	2.98E+00	1.06E-01	4.05E-01	3.37E-02	ND	ND
PCB101	1.82E+02	1.77E+01	3.30E+01	1.96E+00	1.31E+01	7.91E-01
PCB99	4.27E+01	5.10E+00	7.83E+00	4.33E-01	3.13E+00	2.11E-01
PCB119	3.98E+00	4.06E-01	9.64E-01	7.03E-02	3.84E-01	
PCB83	2.89E+00	2.40E-01	6.16E-01	9.03E-02	ND	ND
PCB97	1.10E+01	1.00E+00	1.84E+00	1.09E-01	7.01E-01	9.12E-02
PCB81	6.50E+00	5.08E-01	3.07E+00	5.71E-02	4.59E+00	1.70E+00
PCB87	2.87E+01	2.81E+00	4.56E+00	3.55E-01	1.54E+00	3.43E-01
PCB85	3.48E+01	2.63E+00	5.75E+00	2.73E-01	2.21E+00	1.29E-01
PCB136	7.26E+01	6.64E+00	1.81E+01	7.16E-01	9.45E+00	1.30E-01
PCB110	1.08E+02	1.00E+01	1.57E+01	1.32E+00	7.40E+00	1.35E-01

PCB77	ND	ND	ND	ND	ND	ND
PCB82	ND	ND	ND	ND	ND	ND
PCB151	1.15E+02	9.43E+00	3.00E+01	1.01E+00	1.52E+01	1.71E-01
PCB135	5.62E+01	4.27E+00	1.64E+01	4.96E-01	8.58E+00	3.33E-01
PCB144+124+147	3.09E+01	2.63E+00	8.85E+00	2.26E-01	4.51E+00	1.62E-01
PCB107	2.23E+00	1.52E-01	ND	ND	ND	ND
PCB123+149	2.39E+02	1.97E+01	6.59E+01	2.70E+00	3.45E+01	5.08E-01
PCB118	4.07E+01	3.46E+00	7.21E+00	7.84E-01	1.62E+00	4.90E-01
PCB134	1.14E+01	8.92E-01	3.28E+00	1.16E-01	1.67E+00	7.71E-02
PCB114+131	4.05E+00	6.87E-01	ND	ND	ND	ND
PCB146	5.01E+01	3.56E+00	1.68E+01	3.79E-01	8.81E+00	8.95E-01
PCB153	2.57E+02	1.80E+01	8.52E+01	1.14E+01	4.12E+01	7.79E-01
PCB105	1.35E+01	1.18E+00	4.34E+00		2.28E+00	2.02E-01
PCB132	3.91E+01	3.28E+01	1.25E+00	1.01E-01	3.40E-01	
PCB141	3.35E+01	5.23E+00	3.16E+01	1.86E+01	9.87E+00	3.04E-01
PCB137+176+130	9.87E+00	1.64E-01	6.61E+00	1.13E-01	3.97E+00	1.92E-01
PCB163	1.12E+02	8.39E+00	3.33E+01	1.08E+00	1.78E+01	3.49E-01
PCB138	2.29E+02	1.64E+01	7.07E+01	1.95E+00	3.89E+01	4.12E-02
PCB158	3.33E+01	2.52E+00	1.04E+01	3.12E-01	5.75E+00	1.93E-01
PCB178	3.48E+01	2.30E+00	1.27E+01	3.41E-01	8.12E+00	3.25E-01
PCB187+182	8.67E+01	4.96E+00	3.35E+01	6.88E-01	2.36E+01	4.38E-02
PCB183	5.22E+01	3.05E+00	2.08E+01	3.14E-01	1.43E+01	4.34E-01
PCB128	1.67E+01	1.08E+00	5.23E+00	4.58E-02	2.62E+00	2.29E-01
PCB185	8.47E+00	2.72E-01	3.44E+00	3.48E-03	2.21E+00	2.03E-01
PCB174	8.60E+01	5.28E+00	3.37E+01	7.53E-01	2.26E+01	8.15E-01
PCB177	5.81E+01	3.33E+00	2.33E+01	3.70E-01	1.57E+01	2.11E-01
PCB202	ND	ND	2.00E+00	9.73E-03	1.68E+00	1.81E-02
PCB171	1.63E+01	9.09E-01	6.86E+00	1.25E-01	4.64E+00	8.53E-03
PCB156	8.89E+00	5.73E-01	2.86E+00	1.03E-01	1.53E+00	4.82E-03
PCB157+200	3.04E+00	9.15E-02	2.77E+00	3.27E-02	2.02E+00	2.54E-02
PCB172	ND	ND	ND	ND	ND	ND
PCB197	8.79E-01	1.03E-01	5.35E-01	1.60E-03	5.30E-01	1.55E-01
PCB180	1.55E+02	7.90E+00	6.44E+01	7.69E-01	4.41E+01	8.34E-01
PCB191	4.81E+00	2.16E-01	2.01E+00	7.99E-03	1.26E+00	1.07E-01
PCB199	3.29E+00	2.12E-01	1.91E+00	8.11E-03	1.67E+00	8.15E-02
PCB170+190	6.91E+01	3.58E+00	2.86E+01	4.72E-01	1.95E+01	6.07E-01
PCB198	9.73E-01	6.36E-02	5.47E-01	1.55E-03	4.41E-01	
PCB201	3.07E+01	1.54E+00	1.76E+01	3.24E-02	1.40E+01	2.96E-01
PCB203+196	3.64E+01	1.71E+00	2.13E+01	1.62E-02	1.72E+01	1.37E-01
PCB189	2.17E+00	1.05E-01	1.02E+00	2.90E-03	6.16E-01	
PCB208	3.62E-01	1.14E-02	2.76E-01	5.10E-04	2.79E-01	
PCB195	6.64E+00	4.29E-01	1.94E+01	1.54E+01	3.26E+00	9.78E-03
PCB207	3.34E-01		3.19E-01		2.56E-01	
PCB194	1.58E+01	6.38E-01	9.38E+00	3.48E-02	7.65E+00	1.10E-02
PCB205	1.20E+00	1.08E-01	7.33E-01	2.63E-02	5.94E-01	
PCB206	3.14E+00	2.48E-01	2.06E+00	4.58E-02	1.82E+00	1.17E-01
PCB209	3.54E-01	2.11E-02	3.07E-01	5.02E-03	3.04E-01	
Total PCBs	**2.73E+03**	**1.30E+02**	**8.07E+02**	**3.34E+01**	**4.49E+02**	**1.06E+00**

Sample name	2×2 min mixing, 75-150 µm AC Average (n=2)	Deviation	2 min mixing, <45 µm AC Average (n=2)	Deviation	layered AC Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)						
PCB1	ND	ND	ND	ND	ND	ND
PCB3	ND	ND	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND	ND	ND
PCB6	ND	ND	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND	ND	ND
PCB18	ND	ND	ND	ND	ND	ND
PCB15+17	ND	ND	ND	ND	2.61E+00	
PCB24	ND	ND	ND	ND	ND	ND
PCB27	ND	ND	ND	ND	6.47E+00	
PCB16	ND	ND	ND	ND	ND	ND
PCB32	ND	ND	ND	ND	1.58E+00	2.68E-02
PCB26	ND	ND	ND	ND	ND	ND
PCB25	ND	ND	ND	ND	ND	ND
PCB31+28	ND	ND	ND	ND	ND	ND
PCB21+33+53	ND	ND	ND	ND	1.15E+01	1.87E-01
PCB51	ND	ND	ND	ND	9.33E+00	2.57E-01
PCB22	ND	ND	ND	ND	1.77E+00	5.66E-02
PCB45	ND	ND	ND	ND	ND	ND
PCB46	ND	ND	ND	ND	ND	ND
PCB52+49	ND	ND	ND	ND	3.61E+01	2.24E-01
PCB43	ND	ND	ND	ND	1.54E+01	5.27E-02
PCB47+48	ND	ND	ND	ND	ND	ND
PCB44	ND	ND	ND	ND	9.11E+00	2.60E-01
PCB37	ND	ND	ND	ND	ND	ND
PCB42	ND	ND	ND	ND	2.44E+00	4.45E-02
PCB41	ND	ND	ND	ND	3.67E+00	9.29E-02
PCB71	ND	ND	ND	ND	ND	ND
PCB64	ND	ND	ND	ND	2.43E+00	3.92E-02
PCB40	ND	ND	ND	ND	ND	ND
PCB100	ND	ND	ND	ND	ND	ND
PCB63	ND	ND	ND	ND	ND	ND
PCB74	ND	ND	ND	ND	2.46E+00	
PCB70+76	ND	ND	ND	ND	6.94E+00	9.39E-02
PCB66+95	3.20E+01		ND	ND	ND	ND
PCB91	1.68E+00	2.80E-01	ND	ND	1.23E+01	1.76E-01
PCB56	ND	ND	ND	ND	3.68E+00	7.68E-01
PCB60	ND	ND	ND	ND	5.02E-01	
PCB92+84	3.53E+00	7.24E-01	2.16E+00		5.09E+01	2.76E-01
PCB89	4.60E-01		ND	ND	3.45E+00	5.27E-02
PCB101	3.35E+01	4.52E+00	1.12E+01	4.03E+00	2.25E+02	1.55E+00
PCB99	8.35E+00	1.51E+00	3.22E+00	9.48E-01	4.35E+01	1.92E-01
PCB119	1.62E+00	5.63E-01	3.65E-01	3.80E-02	3.94E+00	8.91E-03
PCB83	7.30E-01		ND	ND	3.73E+00	9.68E-02
PCB97	1.81E+00	2.51E-01	6.90E-01	3.43E-01	1.36E+01	2.28E-01
PCB81	4.05E+00	9.37E-02	3.44E+00	2.64E-01	7.00E+00	5.11E-01
PCB87	4.27E+00	6.54E-01	1.40E+00	8.42E-01	3.69E+01	7.81E-01
PCB85	5.72E+00	4.70E-01	2.16E+00	8.80E-01	3.91E+01	6.75E-01
PCB136	1.95E+01	2.35E+00	6.42E+00	1.94E+00	9.15E+01	1.15E+00
PCB110	1.33E+01		6.19E+00	2.50E+00	1.33E+02	1.53E+00
PCB77	ND	ND	ND	ND	3.37E-01	
PCB82	ND	ND	ND	ND	ND	ND

PCB151	3.26E+01	3.42E+00	1.33E+01	2.66E+00	1.39E+02	1.40E+00
PCB135	1.78E+01	1.86E+00	7.09E+00	1.84E+00	6.71E+01	9.01E-01
PCB144+124+147	9.68E+00	8.94E-01	4.20E+00	1.06E+00	3.75E+01	5.54E-01
PCB107	ND	ND	ND	ND	2.75E+00	3.83E-02
PCB123+149	6.93E+01	6.97E+00	2.95E+01	6.37E+00	2.83E+02	6.47E-01
PCB118	6.37E+00	9.26E-01	2.11E+00	9.76E-01	4.94E+01	2.99E-01
PCB134	3.71E+00	5.78E-01	1.52E+00	4.14E-01	1.40E+01	1.86E-01
PCB114+131	ND	ND	ND	ND	5.10E+00	
PCB146	1.83E+01	1.47E+00	9.68E+00	1.79E+00	5.68E+01	1.03E-01
PCB153	8.23E+01	8.03E+00	4.31E+01	7.70E+00	2.79E+02	2.15E+00
PCB105	3.97E+00	1.50E-01	1.60E+00	6.09E-01	1.91E+01	7.91E-04
PCB132	9.86E-01	1.77E-01	3.81E-01		7.84E+00	4.70E-02
PCB141	1.68E+01	1.37E+00	7.21E+00	1.23E+00	4.47E+01	1.89E-01
PCB137+176+130	7.03E+00	5.50E-01	3.40E+00	4.24E-01	1.08E+01	1.25E-01
PCB163	3.36E+01	2.64E+00	1.72E+01	3.49E+00	1.25E+02	7.50E-01
PCB138	7.15E+01	6.08E+00	3.78E+01	7.08E+00	2.60E+02	1.39E+00
PCB158	1.07E+01	7.74E-01	6.00E+00	1.05E+00	3.71E+01	2.39E-01
PCB178	1.35E+01	1.15E+00	7.39E+00	9.71E-01	3.92E+01	3.43E-01
PCB187+182	3.49E+01	2.92E+00	2.09E+01	2.63E+00	9.46E+01	4.25E-01
PCB183	2.20E+01	1.47E+00	1.26E+01	1.64E+00	5.75E+01	5.14E-01
PCB128	5.71E+00	2.30E-01	2.29E+00	4.44E-01	1.86E+01	2.47E-01
PCB185	3.78E+00	1.56E-01	2.11E+00	3.28E-01	9.51E+00	1.58E-04
PCB174	3.41E+01	2.52E+00	1.92E+01	2.64E+00	9.52E+01	6.53E-01
PCB177	2.40E+01	1.67E+00	1.29E+01	1.20E+00	6.38E+01	4.28E-01
PCB202	2.31E+00	9.15E-02	1.23E+00	9.87E-02	3.56E+00	
PCB171	7.02E+00	4.58E-01	3.82E+00	5.32E-01	1.74E+01	1.93E-01
PCB156	2.74E+00	1.97E-01	1.72E+00	2.81E-01	9.66E+00	7.47E-02
PCB157+200	2.93E+00	1.29E-01	1.68E+00	1.59E-01	3.14E+00	
PCB172	ND	ND	ND	ND	ND	ND
PCB197	6.04E-01		ND	ND	8.67E-01	2.67E-02
PCB180	6.39E+01	3.47E+00	3.88E+01	4.53E+00	1.64E+02	9.37E-01
PCB191	2.15E+00	3.20E-01	1.04E+00	2.12E-01	5.24E+00	6.18E-02
PCB199	2.04E+00	1.41E-01	1.17E+00	4.53E-02	3.43E+00	
PCB170+190	2.77E+01	1.58E+00	1.59E+01	1.98E+00	7.20E+01	5.18E-01
PCB198	5.86E-01	2.62E-02	2.68E-01		9.48E-01	1.08E-02
PCB201	1.93E+01	6.54E-01	9.01E+00		3.07E+01	2.51E-01
PCB203+196	2.30E+01	6.96E-01	1.25E+01	1.07E+00	3.48E+01	1.67E-01
PCB189	1.01E+00	8.54E-02	5.72E-01	4.98E-02	2.27E+00	2.35E-02
PCB208	3.16E-01	3.19E-02	1.57E-01		3.13E-01	8.76E-03
PCB195	4.27E+00	1.48E-01	2.19E+00	1.19E-01	6.69E+00	9.48E-02
PCB207	ND	ND	ND	ND	3.62E-01	1.57E-02
PCB194	9.76E+00	1.98E-01	5.43E+00	5.43E-01	1.51E+01	1.22E-01
PCB205	8.29E-01	5.08E-02	3.85E-01		1.27E+00	1.83E-01
PCB206	2.35E+00	1.35E-02	1.25E+00	2.79E-01	2.92E+00	
PCB209	3.46E-01	8.72E-04	ND	ND	2.90E-01	1.82E-02
Total PCBs	**8.03E+02**	**7.60E+01**	**3.90E+02**	**6.41E+01**	**2.96E+03**	**1.98E+00**

Test Title	Sediment column studies					
Sample Sets	No-Flow, 3 month contact					
Sample name	control		2 min mixing, 75-150 μm AC		30 min mixing, 75-150 μm AC	
	Average (n=2)	Deviation	Average (n=2)	Deviation	Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)						
PCB1	ND	ND	ND	ND	ND	ND
PCB3	ND	ND	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND	ND	ND
PCB6	ND	ND	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND	ND	ND
PCB18	ND	ND	ND	ND	ND	ND
PCB15+17	1.77E+00	ND	ND	ND	ND	ND
PCB24	ND	ND	ND	ND	ND	ND
PCB27	ND	ND	ND	ND	ND	ND
PCB16	ND	ND	ND	ND	ND	ND
PCB32	1.74E+00	ND	ND	ND	ND	ND
PCB26	ND	ND	ND	ND	ND	ND
PCB25	ND	ND	ND	ND	ND	ND
PCB31+28	ND	ND	ND	ND	ND	ND
PCB21+33+53	1.14E+01	8.44E-01	ND	ND	ND	ND
PCB51	9.92E+00	7.19E-01	ND	ND	ND	ND
PCB22	2.62E+00	1.21E-01	ND	ND	ND	ND
PCB45	ND	ND	ND	ND	ND	ND
PCB46	ND	ND	ND	ND	ND	ND
PCB52+49	3.44E+01	2.32E-01	ND	ND	ND	ND
PCB43	1.64E+01	6.60E-02	ND	ND	ND	ND
PCB47+48	ND	ND	ND	ND	ND	ND
PCB44	7.63E+00	9.03E-01	ND	ND	ND	ND
PCB37	ND	ND	ND	ND	ND	ND
PCB42	2.17E+00	2.26E-01	ND	ND	ND	ND
PCB41	3.80E+00	1.86E-01	ND	ND	ND	ND
PCB71	ND	ND	ND	ND	ND	ND
PCB64	2.00E+00	2.51E-01	ND	ND	ND	ND
PCB40	ND	ND	ND	ND	ND	ND
PCB100	ND	ND	ND	ND	ND	ND
PCB63	ND	ND	ND	ND	ND	ND
PCB74	6.76E+00	ND	ND	ND	ND	ND
PCB70+76	7.27E+00	6.60E-01	ND	ND	ND	ND
PCB66+95	ND	ND	ND	ND	ND	ND
PCB91	1.47E+01	9.82E-01	ND	ND	4.60E-01	ND
PCB56	2.79E+00	3.69E-01	ND	ND	ND	ND
PCB60	ND	ND	ND	ND	ND	ND
PCB92+84	4.94E+01	4.62E+00	1.53E+00	7.03E-01	1.19E+00	ND
PCB89	5.46E+00	2.60E-01	ND	ND	ND	ND
PCB101	2.29E+02	1.50E+01	2.29E+01	1.22E+01	1.37E+01	ND
PCB99	5.69E+01	4.07E+00	3.47E+00	1.87E-01	4.18E+00	ND
PCB119	5.00E+00	2.47E-01	4.49E-01	ND	5.16E-01	7.11E-02
PCB83	4.06E+00	1.26E-01	ND	ND	ND	ND
PCB97	1.52E+01	1.17E+00	7.81E-01	3.01E-01	6.80E-01	1.61E-02
PCB81	7.54E+00	5.11E-02	3.48E+00	9.78E-02	3.88E+00	6.91E-01
PCB87	3.93E+01	2.01E+00	2.78E+00	1.58E+00	1.31E+00	4.28E-01
PCB85	4.17E+01	2.79E+00	2.11E+00	5.31E-02	2.27E+00	9.36E-02
PCB136	8.93E+01	8.65E+00	1.48E+01	7.09E+00	9.91E+00	2.12E+00
PCB110	1.30E+02	3.79E+00	5.78E+00	ND	6.52E+00	5.84E-01

PCB77	ND	ND	ND	ND	ND	ND
PCB82	ND	ND	ND	ND	ND	ND
PCB151	1.70E+02	8.38E+00	2.80E+01	1.12E+01	2.10E+01	3.05E+00
PCB135	7.84E+01	4.58E+00	1.50E+01	5.38E+00	1.17E+01	1.51E+00
PCB144+124+147	4.46E+01	2.49E+00	8.92E+00	3.61E+00	6.57E+00	9.27E-01
PCB107	5.09E+00	4.79E-01	ND	ND	ND	ND
PCB123+149	3.20E+02	2.35E+01	6.11E+01	2.43E+01	4.53E+01	6.53E+00
PCB118	6.48E+01	2.68E+00	3.64E+00	1.84E+00	2.55E+00	5.69E-01
PCB134	1.59E+01	1.10E+00	2.96E+00	1.10E+00	2.23E+00	2.39E-01
PCB114+131	4.88E+00	ND	ND	ND	ND	ND
PCB146	8.01E+01	1.19E+00	1.67E+01	4.47E+00	1.39E+01	1.09E+00
PCB153	3.88E+02	1.82E+01	8.16E+01	2.64E+01	6.20E+01	6.27E+00
PCB105	1.91E+01	1.84E-01	3.86E+00	1.67E+00	2.30E+00	3.34E-01
PCB132	1.01E+01	1.41E+00	5.39E-01	ND	2.64E-01	ND
PCB141	7.45E+01	7.91E+00	1.92E+01	5.59E+00	1.63E+01	4.94E-01
PCB137+176+130	1.65E+01	3.56E-02	7.62E+00	2.31E+00	5.99E+00	7.14E-01
PCB163	1.61E+02	7.18E+00	3.36E+01	1.18E+01	2.25E+01	2.73E+00
PCB138	3.41E+02	1.62E+01	7.24E+01	2.61E+01	4.86E+01	5.11E+00
PCB158	5.42E+01	1.65E+00	1.12E+01	4.09E+00	7.21E+00	8.12E-01
PCB178	6.23E+01	2.36E+00	1.61E+01	4.84E+00	1.26E+01	9.70E-01
PCB187+182	1.56E+02	3.72E-01	4.44E+01	1.27E+01	3.47E+01	1.76E+00
PCB183	9.66E+01	1.61E-01	2.90E+01	8.61E+00	2.07E+01	1.87E+00
PCB128	2.33E+01	1.69E+00	4.30E+00	1.59E+00	2.64E+00	5.02E-01
PCB185	1.51E+01	1.25E-01	4.55E+00	1.40E+00	3.04E+00	1.11E-01
PCB174	1.43E+02	2.41E+00	4.33E+01	1.40E+01	3.07E+01	2.32E+00
PCB177	9.64E+01	1.49E+00	3.02E+01	8.85E+00	2.10E+01	2.42E+00
PCB202	6.00E+00	2.48E-01	2.95E+00	5.47E-01	2.45E+00	8.47E-03
PCB171	2.71E+01	1.62E-01	9.06E+00	2.66E+00	6.28E+00	5.53E-01
PCB156	1.41E+01	4.46E-01	3.20E+00	1.24E+00	1.82E+00	1.97E-01
PCB157+200	6.09E+00	2.48E-01	2.92E+00	6.16E-01	2.39E+00	3.08E-02
PCB172	3.10E+01	1.22E+00	1.00E+01	2.73E+00	4.98E+00	9.03E-02
PCB197	1.75E+00	4.99E-02	2.45E+00	1.48E+00	7.00E-01	8.88E-02
PCB180	2.76E+02	3.20E-01	8.92E+01	2.79E+01	5.66E+01	3.06E+00
PCB191	8.74E+00	6.64E-02	2.59E+00	7.78E-01	1.74E+00	6.82E-02
PCB199	5.63E+00	2.30E-01	2.94E+00	7.03E-01	2.19E+00	5.64E-02
PCB170+190	1.13E+02	1.73E+00	3.84E+01	1.27E+01	2.25E+01	1.85E+00
PCB198	1.87E+00	1.10E-01	8.48E-01	2.01E-01	5.73E-01	2.75E-03
PCB201	5.40E+01	1.60E+00	2.69E+01	6.34E+00	1.82E+01	3.90E-01
PCB203+196	6.69E+01	8.77E-01	3.25E+01	7.54E+00	2.17E+01	3.16E-01
PCB189	4.34E+00	3.98E-01	1.45E+00	4.30E-01	7.44E-01	3.85E-02
PCB208	6.53E-01	1.03E-02	4.53E-01	6.98E-02	3.37E-01	1.77E-02
PCB195	1.23E+01	1.45E-01	6.30E+00	1.71E+00	3.89E+00	7.51E-02
PCB207	6.57E-01	ND	4.79E-01	1.02E-01	2.95E-01	ND
PCB194	2.89E+01	2.15E-01	1.47E+01	3.92E+00	8.85E+00	1.60E-01
PCB205	2.10E+00	6.94E-02	9.99E-01	1.97E-01	5.92E-01	3.23E-02
PCB206	4.62E+00	ND	2.92E+00	6.75E-01	1.94E+00	1.89E-02
PCB209	5.52E-01	4.07E-02	3.86E-01	1.17E-02	3.33E-01	1.10E-02
Total PCBs	**3.90E+03**	**1.13E+02**	**8.44E+02**	**2.70E+02**	**5.87E+02**	**5.88E+01**

Sample name	2×2 min mixing, 75-150 μm AC Average (n=2)	Deviation	2 min mixing, <45 μm AC Average (n=2)	Deviation	layered AC Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)						
PCB1	ND	ND	ND	ND	ND	ND
PCB3	ND	ND	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND	ND	ND
PCB6	ND	ND	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND	ND	ND
PCB18	ND	ND	ND	ND	ND	ND
PCB15+17	ND	ND	ND	ND	2.57E+00	1.97E-01
PCB24	ND	ND	ND	ND	ND	ND
PCB27	ND	ND	ND	ND	1.00E+01	2.70E-01
PCB16	ND	ND	ND	ND	ND	ND
PCB32	ND	ND	ND	ND	2.27E+00	1.87E-01
PCB26	ND	ND	ND	ND	ND	ND
PCB25	ND	ND	ND	ND	ND	ND
PCB31+28	ND	ND	ND	ND	ND	ND
PCB21+33+53	ND	ND	ND	ND	1.72E+01	5.14E-01
PCB51	ND	ND	ND	ND	1.38E+01	4.52E-01
PCB22	ND	ND	ND	ND	3.13E+00	8.67E-02
PCB45	ND	ND	ND	ND	5.22E-01	ND
PCB46	ND	ND	ND	ND	7.39E-01	ND
PCB52+49	ND	ND	ND	ND	4.86E+01	1.46E+00
PCB43	ND	ND	ND	ND	2.34E+01	9.35E-01
PCB47+48	ND	ND	ND	ND	ND	ND
PCB44	ND	ND	ND	ND	1.23E+01	ND
PCB37	ND	ND	ND	ND	ND	ND
PCB42	ND	ND	ND	ND	3.30E+00	7.88E-02
PCB41	ND	ND	ND	ND	5.44E+00	6.26E-02
PCB71	ND	ND	ND	ND	ND	ND
PCB64	ND	ND	ND	ND	3.32E+00	1.27E-01
PCB40	ND	ND	ND	ND	ND	ND
PCB100	ND	ND	ND	ND	ND	ND
PCB63	ND	ND	ND	ND	ND	ND
PCB74	ND	ND	ND	ND	4.88E+00	3.59E-01
PCB70+76	ND	ND	ND	ND	1.07E+01	2.53E-01
PCB66+95	ND	ND	ND	ND	ND	ND
PCB91	ND	ND	ND	ND	2.08E+01	3.86E-01
PCB56	ND	ND	ND	ND	3.55E+00	3.04E-01
PCB60	ND	ND	ND	ND	ND	ND
PCB92+84	1.01E+00	2.03E-02	ND	ND	7.50E+01	1.23E-01
PCB89	ND	ND	ND	ND	6.59E+00	8.16E-02
PCB101	1.40E+01	7.69E-01	3.26E+00	2.74E-01	2.65E+02	5.80E-01
PCB99	3.90E+00	1.58E-01	1.14E+00	7.21E-02	5.53E+01	2.33E+00
PCB119	5.07E-01	3.12E-03	ND	ND	6.05E+00	4.33E-01
PCB83	ND	ND	ND	ND	5.62E+00	1.25E-01
PCB97	6.98E-01	3.29E-02	ND	ND	2.06E+01	9.24E-02
PCB81	3.64E+00	4.82E-01	3.70E+00	2.54E-01	9.31E+00	8.87E-02
PCB87	1.61E+00	1.71E-01	ND	ND	5.10E+01	4.23E-01
PCB85	2.41E+00	2.56E-01	4.25E-01	9.07E-02	4.60E+01	1.76E+00
PCB136	1.24E+01	1.20E-01	2.66E+00	1.32E-01	1.10E+02	5.69E-02
PCB110	7.14E+00	2.31E-01	2.24E+00	9.76E-02	1.42E+02	8.69E-01
PCB77	ND	ND	ND	ND	1.87E+00	ND
PCB82	ND	ND	ND	ND	ND	ND

PCB151	2.68E+01	5.04E-01	8.63E+00	3.92E-01	1.64E+02	1.45E-01
PCB135	1.46E+01	2.15E-01	4.16E+00	1.05E-01	8.71E+01	6.21E-01
PCB144+124+147	8.49E+00	1.79E-01	2.91E+00	7.70E-02	4.64E+01	1.64E-01
PCB107	ND	ND	ND	ND	4.69E+00	6.38E-01
PCB123+149	5.91E+01	7.50E-01	1.88E+01	6.00E-01	3.48E+02	1.67E-01
PCB118	3.41E+00	6.12E-02	ND	ND	7.28E+01	2.40E+00
PCB134	2.80E+00	2.44E-02	8.27E-01	2.08E-02	1.76E+01	1.44E-01
PCB114+131	ND	ND	ND	ND	ND	ND
PCB146	1.77E+01	5.47E-01	8.03E+00	4.53E-01	7.75E+01	1.47E-01
PCB153	8.38E+01	4.10E+00	3.58E+01	9.34E-01	3.76E+02	2.02E+00
PCB105	3.21E+00	3.21E-01	7.21E-01	1.04E-01	2.16E+01	7.44E-01
PCB132	2.84E-01	3.30E-02	ND	ND	1.24E+01	1.60E-01
PCB141	2.39E+01	1.15E+00	1.11E+01	3.31E-01	7.19E+01	1.07E+01
PCB137+176+130	8.34E+00	2.44E-01	3.37E+00	2.19E-01	1.71E+01	1.77E-01
PCB163	3.29E+01	1.02E+00	1.13E+01	6.44E-01	1.61E+02	2.30E-01
PCB138	6.96E+01	2.20E+00	2.64E+01	9.98E-01	3.41E+02	1.45E+00
PCB158	1.08E+01	2.79E-01	4.29E+00	1.32E-01	5.27E+01	7.46E-01
PCB178	1.82E+01	7.62E-01	8.35E+00	2.12E-01	6.01E+01	9.80E-01
PCB187+182	5.02E+01	2.29E+00	2.45E+01	5.77E-01	1.49E+02	2.33E+00
PCB183	3.17E+01	1.84E+00	1.48E+01	7.03E-03	8.94E+01	1.58E+00
PCB128	4.09E+00	3.20E-02	1.15E+00	6.74E-02	2.59E+01	4.55E-02
PCB185	4.65E+00	2.32E-01	2.22E+00	6.58E-02	1.43E+01	2.47E-01
PCB174	4.79E+01	1.93E+00	2.00E+01	4.95E-01	1.42E+02	2.17E+00
PCB177	3.33E+01	1.45E+00	1.39E+01	1.07E-01	9.61E+01	1.75E+00
PCB202	3.32E+00	1.60E-01	1.70E+00	4.15E-02	5.29E+00	1.05E-02
PCB171	9.77E+00	4.78E-01	4.22E+00	1.57E-01	2.49E+01	1.65E+00
PCB156	2.91E+00	1.46E-01	1.21E+00	5.61E-02	1.34E+01	1.43E-01
PCB157+200	3.32E+00	2.56E-01	1.59E+00	7.99E-02	5.14E+00	2.37E-01
PCB172	1.04E+01	4.08E-01	4.65E+00	9.70E-01	2.61E+01	2.70E-01
PCB197	8.58E-01	4.81E-02	4.80E-01	1.69E-02	1.48E+00	2.00E-02
PCB180	9.38E+01	5.66E+00	4.19E+01	9.31E-01	2.46E+02	3.83E+00
PCB191	2.70E+00	1.11E-01	1.10E+00	2.54E-02	7.78E+00	2.29E-01
PCB199	3.19E+00	2.04E-01	1.51E+00	5.22E-02	4.83E+00	7.54E-03
PCB170+190	3.98E+01	2.40E+00	1.57E+01	4.43E-01	1.05E+02	1.99E+00
PCB198	1.06E+00	ND	3.59E-01	3.01E-02	1.48E+00	1.72E-02
PCB201	3.13E+01	ND	1.23E+01	2.65E-01	4.53E+01	3.90E-01
PCB203+196	3.37E+01	2.40E+00	1.54E+01	2.21E-01	5.43E+01	6.50E-01
PCB189	1.39E+00	1.25E-01	6.15E-01	2.38E-02	3.46E+00	1.30E-01
PCB208	4.72E-01	1.92E-02	2.29E-01	8.02E-03	2.19E+00	1.68E+00
PCB195	6.58E+00	4.86E-01	2.72E+00	6.58E-03	1.03E+01	1.72E-01
PCB207	4.95E-01	4.50E-02	ND	ND	4.59E-01	3.19E-02
PCB194	1.51E+01	1.24E+00	6.26E+00	9.40E-02	2.28E+01	3.78E-01
PCB205	1.01E+00	1.06E-01	5.12E-01	ND	1.60E+00	7.60E-03
PCB206	3.38E+00	3.74E-01	1.20E+00	2.40E-02	3.68E+00	6.85E-02
PCB209	4.66E-01	2.07E-02	2.08E-01	ND	3.82E-01	1.14E-02
Total PCBs	**8.52E+02**	**5.15E+01**	**3.48E+02**	**9.81E+00**	**4.01E+03**	**1.77E+01**

Test Title	Sediment column studies					
Sample Sets	No-Flow, 24 month contact					
Sample name	control		2 min mixing, 75-150 μm AC		30 min mixing, 75-150 μm AC	
	Average (n=2)	Deviation	Average (n=2)	Deviation	Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)						
PCB1	ND	ND	ND	ND	ND	ND
PCB3	ND	ND	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND	ND	ND
PCB7+9	ND	ND	1.36E+00	ND	ND	ND
PCB6	ND	ND	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND	ND	ND
PCB18	ND	ND	ND	ND	ND	ND
PCB15+17	9.70E+00	5.67E-02	ND	ND	ND	ND
PCB24	ND	ND	ND	ND	ND	ND
PCB27	ND	ND	ND	ND	ND	ND
PCB16	ND	ND	ND	ND	ND	ND
PCB32	2.19E+00	ND	ND	ND	ND	ND
PCB26	4.80E+00	2.15E-01	8.94E-01	ND	7.54E-01	2.59E-02
PCB25	ND	ND	ND	ND	1.03E+00	5.20E-02
PCB31+28	ND	ND	ND	ND	ND	ND
PCB21+33+53	1.48E+01	ND	ND	ND	ND	ND
PCB51	1.53E+01	9.07E-01	ND	ND	ND	ND
PCB22	ND	ND	ND	ND	ND	ND
PCB45	9.22E-01	1.01E+00	ND	ND	ND	ND
PCB46	ND	ND	ND	ND	ND	ND
PCB52+49	4.94E+01	1.05E+00	ND	ND	ND	ND
PCB43	2.64E+01	2.22E+00	5.06E+00	ND	ND	ND
PCB47+48	ND	ND	ND	ND	ND	ND
PCB44	1.11E+01	4.16E-01	ND	ND	ND	ND
PCB37	ND	ND	ND	ND	ND	ND
PCB42	4.20E+00	1.07E-01	1.00E+00	1.92E-01	1.10E+00	6.35E-02
PCB41	5.91E+00	2.88E-01	ND	ND	ND	ND
PCB71	ND	ND	ND	ND	ND	ND
PCB64	3.12E+00	1.34E-01	ND	ND	ND	ND
PCB40	ND	ND	ND	ND	ND	ND
PCB100	ND	ND	ND	ND	ND	ND
PCB63	ND	ND	4.74E+00	ND	3.43E+00	8.45E-02
PCB74	2.75E+00	2.17E-01	#DIV/0!	ND	ND	ND
PCB70+76	8.61E+00	ND	ND	ND	ND	ND
PCB66+95	ND	ND	ND	ND	ND	ND
PCB91	1.96E+01	8.73E-01	2.68E+00	1.34E+00	2.60E+00	3.46E-01
PCB56	2.91E+00	1.86E-01	ND		ND	ND
PCB60	ND	ND	ND		ND	ND
PCB92+84	7.14E+01	2.83E+00	2.15E+00	1.26E-02	8.70E-01	ND
PCB89	6.78E+00	4.66E-01	ND		ND	ND
PCB101	2.99E+02	7.05E+00	2.77E+01	4.38E+00	1.13E+01	7.01E-01
PCB99	8.18E+01	4.88E+00	8.34E+00	6.65E-02	3.71E+00	9.62E-02
PCB119	6.94E+00	6.61E-01	1.34E+00	2.66E-01	5.47E-01	9.06E-02
PCB83	5.49E+00	3.60E-01	4.40E-01	7.97E-02	3.49E-01	
PCB97	2.06E+01	6.66E-01	1.43E+00	1.15E-01	6.86E-01	3.18E-02
PCB81	7.34E+00	4.16E-01	6.17E+00	3.45E+00	2.04E+00	3.90E-01
PCB87	5.30E+01	2.23E-01	2.80E+00	ND	1.10E+00	1.46E-01
PCB85	6.88E+01	3.56E+00	4.50E+00	ND	2.01E+00	4.93E-02
PCB136	1.20E+02	2.61E+00	2.24E+01	2.33E+00	1.03E+01	1.10E+00
PCB110	2.01E+02	7.95E-01	1.16E+01	ND	5.81E+00	2.17E-01

PCB77	ND	ND	1.82E+00	ND	1.90E+00	1.18E-01
PCB82	3.86E+00	5.32E-02	ND	ND	ND	ND
PCB151	1.82E+02	2.35E+00	5.12E+01	5.53E+00	2.60E+01	2.07E+00
PCB135	1.01E+02	8.47E-01	2.67E+01	2.36E+00	1.39E+01	6.40E-01
PCB144+124+147	5.36E+01	3.76E-02	1.56E+01	1.69E+00	8.12E+00	4.94E-01
PCB107	5.09E+00	8.79E-01	ND	ND	ND	ND
PCB123+149	4.07E+02	9.09E+00	1.15E+02	1.14E+01	5.98E+01	4.34E+00
PCB118	8.10E+01	7.63E-01	7.43E+00	1.69E+00	1.61E+00	2.81E-01
PCB134	2.14E+01	1.96E-01	5.23E+00	3.67E-01	2.73E+00	2.39E-01
PCB114+131	ND	ND	ND	ND	ND	ND
PCB146	9.26E+01	1.81E+00	3.21E+01	9.59E-01	1.86E+01	3.93E-01
PCB153	4.50E+02	2.32E+00	1.57E+02	5.34E+00	8.78E+01	3.85E+00
PCB105	2.70E+01	2.54E+00	6.92E+00	1.61E+00	3.67E+00	5.81E-03
PCB132	1.53E+01	2.23E-01	1.82E+00	2.83E-01	2.54E-01	ND
PCB141	8.69E+01	1.95E+00	3.93E+01	2.17E+00	2.92E+01	1.76E+00
PCB137+176+130	1.80E+01	2.94E-02	1.42E+01	7.85E-01	8.32E+00	1.39E+00
PCB163	1.93E+02	2.88E-01	6.22E+01	5.30E+00	3.38E+01	1.52E+00
PCB138	4.17E+02	3.49E-01	1.32E+02	9.62E+00	7.33E+01	2.59E+00
PCB158	6.91E+01	1.86E-01	1.95E+01	1.81E+00	1.04E+01	6.76E-01
PCB178	7.19E+01	2.50E-01	3.77E+01	5.19E+00	3.14E+01	2.30E-01
PCB187+182	1.86E+02	1.68E+00	8.95E+01	4.05E+00	6.32E+01	1.06E+00
PCB183	1.09E+02	8.82E-01	5.57E+01	2.15E+00	3.96E+01	8.60E-01
PCB128	2.85E+01	1.73E-01	9.33E+00	2.88E-01	5.99E+00	5.41E-01
PCB185	1.66E+01	3.52E-02	8.31E+00	4.73E-01	5.92E+00	2.55E-01
PCB174	1.79E+02	8.26E-01	8.92E+01	2.46E+00	6.36E+01	1.28E+00
PCB177	1.19E+02	1.33E-01	6.14E+01	1.24E+00	4.37E+01	8.60E-01
PCB202	5.97E+00	1.78E-01	4.74E+00	4.11E-01	4.07E+00	4.25E-02
PCB171	3.18E+01	8.12E-02	1.77E+01	8.51E-01	1.31E+01	4.43E-01
PCB156	1.31E+01	4.24E-01	5.06E+00	1.94E-01	3.10E+00	2.72E-01
PCB157+200	6.11E+00	1.89E-01	5.07E+00	2.73E-01	5.04E+00	8.49E-01
PCB172	3.35E+01	1.70E-02	1.91E+01	7.69E-01	1.27E+01	1.14E+00
PCB197	1.80E+00	1.88E-02	1.46E+00	1.64E-01	1.15E+00	1.76E-01
PCB180	3.07E+02	2.82E+00	1.66E+02	1.03E+00	1.18E+02	8.13E-01
PCB191	9.35E+00	1.13E-01	5.57E+00	3.54E-01	4.14E+00	2.47E-01
PCB199	5.54E+00	2.50E-01	4.57E+00	3.18E-01	3.87E+00	7.40E-02
PCB170+190	1.31E+02	7.08E-01	7.19E+01	3.05E-01	5.11E+01	5.78E-01
PCB198	1.93E+00	3.97E-02	1.48E+00	1.19E-01	1.37E+00	2.61E-02
PCB201	5.49E+01	1.71E+00	4.25E+01	1.11E+00	3.53E+01	2.00E+00
PCB203+196	6.56E+01	1.86E+00	5.05E+01	4.24E-01	4.24E+01	1.04E+00
PCB189	3.66E+00	6.29E-02	2.08E+00	7.53E-02	1.41E+00	3.29E-02
PCB208	5.67E-01	1.19E-02	5.27E-01	2.80E-02	5.01E-01	1.46E-02
PCB195	1.18E+01	3.13E-01	9.31E+00	6.69E-02	7.76E+00	1.49E-01
PCB207	5.62E-01	4.77E-02	6.19E-01	6.65E-02	6.07E-01	2.63E-02
PCB194	2.60E+01	1.06E+00	2.08E+01	7.75E-02	1.69E+01	3.63E-01
PCB205	1.71E+00	1.28E-01	1.78E+00	4.24E-01	1.57E+00	1.13E-01
PCB206	3.67E+00	1.10E-01	4.18E+00	5.72E-01	4.13E+00	1.13E-02
PCB209	4.25E-01	2.60E-02	4.24E-01	4.36E-02	4.56E-01	3.94E-03
Total PCBs	**7.99E+03**	**3.54E+02**	**5.85E+02**	**1.40E+02**	**2.34E+02**	**7.16E+01**

Sample name	2×2 min mixing, 75-150 µm AC Average (n=2)	Deviation	2 min mixing, <45 µm AC Average (n=2)	Deviation	layered AC Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)						
PCB1	ND	ND	ND	ND	ND	ND
PCB3	ND	ND	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND	ND	ND
PCB6	ND	ND	1.55E+00	ND	ND	ND
PCB8+5	ND	ND	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND	ND	ND
PCB18	ND	ND	ND	ND	ND	ND
PCB15+17	ND	ND	ND	ND	3.24E+00	8.16E-01
PCB24	ND	ND	ND	ND	ND	ND
PCB27	ND	ND	ND	ND	ND	ND
PCB16	ND	ND	ND	ND	ND	ND
PCB32	ND	ND	1.60E+00	9.10E-02	3.70E+00	ND
PCB26	9.65E-01	1.15E-01	8.94E-01	ND	3.85E+00	5.93E-01
PCB25	9.93E-01	1.63E-01	8.86E-01	6.20E-02	9.02E-01	4.34E-02
PCB31+28	ND	ND	ND	ND	ND	ND
PCB21+33+53	ND	ND	ND	ND	2.27E+01	ND
PCB51	2.76E+00	ND	1.73E+00	ND	1.62E+01	2.36E+00
PCB22	ND	ND	ND	ND	ND	ND
PCB45	5.12E-01	2.94E-02	8.16E-01	ND	1.08E+00	3.00E-01
PCB46	2.49E+00	ND	ND	ND	1.48E+00	6.59E-01
PCB52+49	ND	ND	ND	ND	5.30E+01	1.02E+01
PCB43	3.15E+00	ND	1.38E+00	ND	3.00E+01	1.64E+00
PCB47+48	ND	ND	ND	ND	ND	ND
PCB44	ND	ND	ND	ND	1.22E+01	2.17E+00
PCB37	ND	ND	ND	ND	ND	ND
PCB42	1.32E+00	1.64E-01	1.07E+00	1.19E-01	3.30E+00	4.89E-01
PCB41	4.11E-01	1.04E-01	ND	ND	6.03E+00	1.16E+00
PCB71	ND	ND	ND	ND	ND	ND
PCB64	ND	ND	ND	ND	3.66E+00	7.51E-01
PCB40	ND	ND	3.10E+00	3.61E-01	ND	ND
PCB100	ND	ND	ND	ND	ND	ND
PCB63	3.29E+00	4.46E-02	3.31E+00	9.54E-01	4.31E+00	4.12E-01
PCB74	ND	ND	ND	ND	4.99E+00	9.08E-01
PCB70+76	ND	ND	ND	ND	9.40E+00	1.65E+00
PCB66+95	ND	ND	ND	ND	ND	ND
PCB91	3.46E+00	8.76E-01	2.46E+00	5.67E-01	2.69E+01	8.15E-02
PCB56	ND	ND	ND	ND	ND	ND
PCB60	ND	ND	ND	ND	ND	ND
PCB92+84	1.45E+00	2.39E-01	ND	ND	8.02E+01	5.59E+00
PCB89	7.24E-01	ND	ND	ND	7.47E+00	5.62E-01
PCB101	2.27E+01	4.75E+00	2.15E+00	2.67E-01	4.29E+02	1.08E+01
PCB99	7.91E+00	2.89E+00	5.39E-01	2.36E-02	8.06E+01	4.49E+00
PCB119	1.14E+00	2.93E-01	3.83E-01	1.87E-01	8.55E+00	2.76E-01
PCB83	5.61E-01	7.64E-02	ND	ND	6.07E+00	8.78E-03
PCB97	1.27E+00	2.99E-01	2.52E-01	ND	2.44E+01	1.17E+00
PCB81	6.02E+00	4.32E-01	1.62E+00	4.92E-02	1.04E+01	3.83E-01
PCB87	3.26E+00	4.55E-01	ND	ND	6.44E+01	2.56E+00
PCB85	3.89E+00	7.65E-01	ND	ND	7.04E+01	3.74E+00
PCB136	1.90E+01	3.41E+00	ND	ND	1.80E+02	2.79E+00
PCB110	1.07E+01	2.18E+00	ND	ND	2.02E+02	1.67E+00
PCB77	1.53E+00	1.18E-01	1.74E+00	ND	2.72E+00	8.07E-02
PCB82	ND	ND	ND	ND	4.12E+00	2.70E-01

PCB151	4.65E+01	9.72E+00	ND	ND	2.73E+02	3.93E+00
PCB135	2.63E+01	4.90E+00	3.15E+00	ND	1.39E+02	1.27E+00
PCB144+124+147	1.37E+01	2.80E+00	ND	ND	7.57E+01	1.14E+00
PCB107	ND	ND	ND	ND	7.10E+00	1.54E-01
PCB123+149	1.04E+02	2.05E+01	ND	ND	5.84E+02	9.97E+00
PCB118	5.91E+00	1.60E+00	ND	ND	9.05E+01	1.83E+00
PCB134	4.81E+00	1.04E+00	ND	ND	2.74E+01	4.69E-01
PCB114+131	ND	ND	1.49E+00	5.13E-02	2.23E+01	3.65E+00
PCB146	3.03E+01	6.39E+00	5.74E-01	1.47E-02	1.21E+02	2.15E+00
PCB153	1.48E+02	3.17E+01	2.12E+00	1.37E-01	6.13E+02	1.42E+01
PCB105	6.09E+00	1.13E+00	6.12E-02	ND	4.03E+01	6.76E+00
PCB132	1.15E+00	1.00E-01	ND	ND	1.55E+01	4.16E-01
PCB141	4.46E+01	1.04E+01	1.52E+00	2.32E-01	1.09E+02	2.30E-01
PCB137+176+130	1.52E+01	3.30E+00	6.66E-01	1.81E-01	2.55E+01	2.85E-01
PCB163	5.84E+01	1.14E+01	9.89E-01	2.90E-02	2.60E+02	1.91E+00
PCB138	1.26E+02	2.73E+01	2.35E+00	1.71E-02	5.52E+02	8.05E+00
PCB158	1.91E+01	3.68E+00	5.11E-01	4.50E-02	8.81E+01	1.74E-01
PCB178	4.50E+01	8.16E+00	8.66E+00	1.19E-01	1.02E+02	5.21E+00
PCB187+182	9.49E+01	2.17E+01	3.29E+00	3.90E-02	2.41E+02	4.80E+00
PCB183	5.91E+01	1.37E+01	2.79E+00	2.11E-01	1.42E+02	3.22E+00
PCB128	8.37E+00	1.58E+00	1.10E+00	8.42E-02	3.70E+01	4.78E-01
PCB185	8.63E+00	2.00E+00	1.48E+00	1.06E-01	2.40E+01	6.12E-01
PCB174	9.38E+01	2.18E+01	2.40E+00	2.82E-02	2.38E+02	5.56E+00
PCB177	6.50E+01	1.49E+01	2.28E+00	5.45E-02	1.54E+02	3.97E+00
PCB202	5.37E+00	1.43E+00	4.45E-01	3.56E-02	8.81E+00	1.71E-01
PCB171	1.91E+01	4.44E+00	7.94E-01	6.76E-02	3.49E+01	5.82E-02
PCB156	5.25E+00	1.21E+00	ND	ND	1.81E+01	2.50E-02
PCB157+200	5.31E+00	1.20E+00	7.00E-01	5.39E-02	8.05E+00	2.19E-01
PCB172	1.98E+01	5.57E+00	1.60E+00	1.14E-01	4.67E+01	4.92E-01
PCB197	1.52E+00	2.92E-01	ND	ND	2.30E+00	3.85E-02
PCB180	1.78E+02	4.25E+01	7.61E+00	1.71E-01	4.22E+02	8.18E+00
PCB191	5.64E+00	1.47E+00	ND	ND	9.54E+00	3.13E-01
PCB199	4.81E+00	1.21E+00	8.05E-01	1.88E-02	8.70E+00	1.28E-01
PCB170+190	7.60E+01	1.79E+01	5.04E+00	2.10E-01	1.45E+02	4.11E-02
PCB198	1.79E+00	4.57E-01	1.64E-01	ND	2.90E+00	7.61E-02
PCB201	4.69E+01	1.19E+01	3.61E+00	1.69E-01	8.03E+01	1.11E+00
PCB203+196	5.74E+01	1.41E+01	6.30E+00	4.72E-01	9.44E+01	1.02E+00
PCB189	2.27E+00	6.76E-01	ND	ND	4.30E+00	6.40E-02
PCB208	5.50E-01	1.14E-01	ND	ND	6.08E-01	3.69E-03
PCB195	1.14E+01	1.49E+00	8.54E-01	3.04E-02	1.72E+01	5.76E-02
PCB207	6.61E-01	8.59E-02	ND	ND	1.14E+00	1.94E-02
PCB194	2.34E+01	5.80E+00	2.16E+00	5.83E-02	3.75E+01	8.65E-02
PCB205	2.33E+00	4.97E-01	3.23E-01	4.46E-03	4.44E+00	6.35E-02
PCB206	4.88E+00	9.06E-01	6.13E-01	3.37E-02	7.21E+00	1.00E-01
PCB209	5.61E-01	1.90E-01	ND	ND	5.28E-01	1.29E-02
Total PCBs	**3.80E+02**	**7.21E+01**	**2.39E+02**	**1.90E+02**	**5.84E+03**	**3.16E+02**

Test Title	Sediment column studies			
Sample Sets	Flow, 1 month contact			
Sample name	control		2 min mixing, 75-150 μm	
	Average (n=2)	Deviation	Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)				
PCB1	ND	ND	1.02E+01	ND
PCB3	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND
PCB6	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND
PCB18	ND	ND	ND	ND
PCB15+17	2.01E+00	ND	ND	ND
PCB24	ND	ND	ND	ND
PCB27	ND	ND	ND	ND
PCB16	ND	ND	ND	ND
PCB32	1.10E+00	ND	ND	ND
PCB26	4.29E+00	5.30E-01	1.50E+00	1.35E-01
PCB25	1.27E+00	2.06E-01	1.35E+00	1.02E-01
PCB31+28	ND	ND	ND	ND
PCB21+33+53	7.90E+00	ND	ND	ND
PCB51	6.22E+00	3.24E-01	1.41E+00	ND
PCB22	ND	ND	ND	ND
PCB45	4.58E-01	1.26E-02	ND	ND
PCB46	ND	ND	6.71E-01	ND
PCB52+49	2.06E+01	1.78E+00	ND	ND
PCB43	1.01E+01	5.63E-01	8.92E-01	1.10E-01
PCB47+48	ND	ND	ND	ND
PCB44	5.09E+00	1.78E-01	ND	ND
PCB37	ND	ND	ND	ND
PCB42	1.82E+00	7.05E-02	6.06E-01	4.91E-02
PCB41	2.11E+00	1.77E-01	3.99E-01	ND
PCB71	ND	ND	ND	ND
PCB64	1.31E+00	8.33E-02	ND	ND
PCB40	ND	ND	ND	ND
PCB100	ND	ND	ND	ND
PCB63	1.49E+00	5.31E-02	1.53E+00	2.33E-02
PCB74	ND	ND	ND	ND
PCB70+76	3.27E+00	1.05E-01	ND	ND
PCB66+95	ND	ND	ND	ND
PCB91	5.45E+00	7.78E-02	1.39E+00	5.63E-02
PCB56	7.17E+00	ND	1.27E+00	ND
PCB60	ND	ND	ND	ND
PCB92+84	2.17E+01	7.40E-01	2.56E+00	4.68E-01
PCB89	1.75E+00	2.50E-02	ND	ND
PCB101	1.10E+02	7.83E+00	2.16E+01	1.61E+00
PCB99	2.59E+01	8.69E-01	5.22E+00	5.76E-01
PCB119	2.88E+00	1.41E-01	1.10E+00	1.97E-01
PCB83	1.81E+00	1.13E-01	5.18E-01	1.51E-02
PCB97	6.52E+00	2.75E-01	1.39E+00	2.36E-01
PCB81	5.54E+00	5.08E-01	2.94E+00	1.73E+00
PCB87	1.65E+01	1.20E+00	3.66E+00	4.03E-01
PCB85	1.98E+01	3.45E-01	4.21E+00	6.42E-01
PCB136	4.83E+01	3.23E+00	1.20E+01	7.17E-01
PCB110	6.65E+01	4.55E+00	1.14E+01	1.29E+00

PCB77	1.88E+00	8.06E-02	ND	ND
PCB82	1.48E+00	1.69E-01	ND	ND
PCB151	6.90E+01	3.08E+00	1.94E+01	4.93E-01
PCB135	3.54E+01	1.07E+00	1.07E+01	6.90E-01
PCB144+124+147	1.94E+01	2.52E-01	5.65E+00	2.97E-01
PCB107	1.52E+00	1.22E-01	ND	ND
PCB123+149	1.48E+02	8.01E+00	4.37E+01	2.05E+00
PCB118	2.23E+01	2.82E+00	4.58E+00	1.24E-01
PCB134	6.67E+00	5.51E-01	2.14E+00	1.05E-01
PCB114+131	1.11E+01	3.79E-01	4.30E+00	ND
PCB146	3.16E+01	2.61E-01	1.17E+01	4.65E-01
PCB153	1.51E+02	9.09E+00	5.16E+01	1.45E+00
PCB105	9.54E+00	5.63E-01	2.97E+00	2.58E-01
PCB132	4.95E+00	1.55E-01	1.29E+00	6.68E-01
PCB141	2.58E+01	1.91E+00	1.06E+01	ND
PCB137+176+130	5.47E+00	3.64E-01	2.39E+00	1.79E-01
PCB163	6.66E+01	2.19E+00	2.19E+01	8.64E-01
PCB138	1.40E+02	5.40E+00	4.86E+01	1.88E+00
PCB158	2.09E+01	7.28E-01	7.88E+00	4.25E-01
PCB178	3.10E+01	8.80E-01	1.86E+01	1.70E+00
PCB187+182	5.03E+01	1.12E+00	2.29E+01	7.80E-01
PCB183	2.98E+01	3.74E-01	1.30E+01	3.45E-01
PCB128	1.12E+01	5.44E-01	4.08E+00	2.60E-01
PCB185	4.85E+00	3.69E-02	2.32E+00	1.57E-01
PCB174	5.19E+01	1.21E+00	2.31E+01	5.56E-01
PCB177	3.50E+01	6.15E-01	1.52E+01	3.19E-01
PCB202	2.32E+00	6.66E-02	1.31E+00	4.61E-02
PCB171	1.09E+01	3.21E-01	5.11E+00	8.05E-02
PCB156	5.57E+00	2.67E-01	2.03E+00	9.52E-02
PCB157+200	2.13E+00	1.24E-01	1.26E+00	1.63E-02
PCB172	1.05E+01	1.29E+00	4.62E+00	5.59E-01
PCB197	ND	ND	ND	ND
PCB180	9.10E+01	1.46E+00	4.29E+01	5.79E-01
PCB191	1.82E+01	1.51E+01	1.26E+00	8.00E-02
PCB199	7.00E+00	5.02E+00	1.67E+00	1.63E-01
PCB170+190	4.17E+01	8.48E-01	2.00E+01	9.18E-02
PCB198	7.87E-01	3.70E-02	6.01E-01	6.42E-03
PCB201	1.70E+01	1.66E-01	1.07E+01	3.74E-01
PCB203+196	2.12E+01	1.72E-01	1.39E+01	3.69E-01
PCB189	1.16E+00	1.42E-02	5.59E-01	3.07E-02
PCB208	1.71E-01	1.42E-04	1.62E-01	4.04E-03
PCB195	3.77E+00	8.97E-04	2.42E+00	7.93E-02
PCB207	3.53E-01	7.64E-03	2.61E-01	1.02E-02
PCB194	8.77E+00	3.45E-02	5.82E+00	2.83E-01
PCB205	1.44E+00	1.78E-01	1.01E+00	2.39E-02
PCB206	2.07E+00	1.20E-02	1.49E+00	1.25E-01
PCB209	ND	ND	ND	ND
Total PCBs	**1.63E+03**	**9.55E+01**	**5.39E+02**	**2.08E+01**

Test Title	Sediment column studies					
Sample Sets	Flow, 3 month contact					
Sample name	control		2 min mixing, 75-150 μm AC		30 min mixing, 75-150 μm AC	
	Average (n=2)	Deviation	Average (n=2)	Deviation	Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)						
PCB1	ND	ND	ND	ND	ND	ND
PCB3	ND	ND	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND	ND	ND
PCB6	ND	ND	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND	ND	ND
PCB18	ND	ND	ND	ND	ND	ND
PCB15+17	1.95E+00	ND	ND	ND	ND	ND
PCB24	ND	ND	ND	ND	ND	ND
PCB27	8.01E+00	ND	ND	ND	ND	ND
PCB16	ND	ND	ND	ND	ND	ND
PCB32	1.98E+00	1.71E-01	ND	ND	ND	ND
PCB26	ND	ND	ND	ND	ND	ND
PCB25	ND	ND	ND	ND	ND	ND
PCB31+28	ND	ND	ND	ND	ND	ND
PCB21+33+53	1.57E+01	6.22E-01	ND	ND	ND	ND
PCB51	1.28E+01	3.66E-01	ND	ND	ND	ND
PCB22	2.43E+00	ND	ND	ND	ND	ND
PCB45	ND	ND	ND	ND	ND	ND
PCB46	ND	ND	ND	ND	ND	ND
PCB52+49	4.44E+01	ND	ND	ND	1.43E+00	ND
PCB43	2.19E+01	1.14E+00	ND	ND	ND	ND
PCB47+48	ND	ND	ND	ND	ND	ND
PCB44	1.06E+01	1.66E-01	ND	ND	ND	ND
PCB37	1.36E+00	ND	ND	ND	ND	ND
PCB42	2.72E+00	1.48E-01	ND	ND	ND	ND
PCB41	5.03E+00	1.27E-01	ND	ND	ND	ND
PCB71	ND		ND	ND	ND	ND
PCB64	3.31E+00	7.25E-02	ND	ND	ND	ND
PCB40	ND	ND	ND	ND	ND	ND
PCB100	ND	ND	ND	ND	ND	ND
PCB63	ND	ND	ND	ND	ND	ND
PCB74	3.72E+00	ND	ND	ND	ND	ND
PCB70+76	9.74E+00	4.15E-01	ND	ND	ND	ND
PCB66+95	ND		ND	ND	ND	ND
PCB91	1.53E+01	4.02E-01	1.01E+00	1.59E-02	3.86E-01	ND
PCB56	6.12E+00	4.22E-01	ND	ND	ND	ND
PCB60	ND		ND	ND	ND	ND
PCB92+84	5.61E+01	2.11E+00	2.57E+00	4.81E-01	1.16E+00	4.09E-02
PCB89	5.23E+00	1.96E-01	ND		5.37E-01	ND
PCB101	2.40E+02	2.24E+01	2.77E+01	7.05E+00	9.13E+00	1.10E+00
PCB99	6.35E+01	2.84E+00	5.09E+00	4.49E-02	2.91E+00	3.68E-01
PCB119	5.66E+00	3.50E-02	6.29E-01	8.07E-03	3.52E-01	ND
PCB83	4.17E+00	1.44E-01	3.21E-01	ND	ND	ND
PCB97	1.61E+01	9.18E-01	1.21E+00	2.03E-01	4.99E-01	1.69E-02
PCB81	8.02E+00	2.22E+00	2.93E+00	4.31E-01	2.75E+00	6.86E-01
PCB87	3.92E+01	2.10E+00	3.60E+00	8.67E-01	1.13E+00	8.77E-02
PCB85	5.48E+01	2.03E+00	3.82E+00	1.35E-01	1.92E+00	1.42E-01
PCB136	9.40E+01	1.00E+01	1.90E+01	3.33E+00	6.61E+00	5.20E-01
PCB110	1.46E+02	6.70E+00	1.29E+01	2.84E+00	5.41E+00	3.59E-01

PCB77	ND	ND	ND	ND	ND	ND
PCB82	ND	ND	ND	ND	ND	ND
PCB151	1.59E+02	1.19E+01	3.33E+01	4.78E+00	1.38E+01	1.45E+00
PCB135	7.10E+01	1.08E+00	1.79E+01	2.17E+00	7.47E+00	6.15E-01
PCB144+124+147	4.17E+01	3.76E+00	1.01E+01	1.29E+00	4.11E+00	2.11E-01
PCB107	3.77E+00	7.10E-01	ND	ND	ND	ND
PCB123+149	3.25E+02	3.49E+01	7.31E+01	9.69E+00	2.91E+01	2.01E+00
PCB118	6.37E+01	3.28E+00	5.35E+00		2.72E+00	3.44E-01
PCB134	1.65E+01	2.58E-01	3.53E+00	4.67E-01	1.41E+00	1.07E-01
PCB114+131	ND	ND	ND	ND	ND	ND
PCB146	7.18E+01	7.19E-01	1.87E+01	1.32E+00	9.70E+00	9.06E-01
PCB153	3.60E+02	3.28E+01	8.90E+01	7.83E+00	4.37E+01	3.13E+00
PCB105	2.07E+01	3.20E-01	4.86E+00	6.93E-01	1.48E+00	1.26E-01
PCB132	1.11E+01	4.62E-01	7.41E-01	1.14E-01	2.94E-01	ND
PCB141	6.96E+01	7.18E+00	2.57E+01	2.63E+00	2.02E+01	7.90E+00
PCB137+176+130	1.41E+01	8.41E-03	8.34E+00	5.48E-01	4.33E+00	1.47E-01
PCB163	1.45E+02	5.83E-01	3.81E+01	3.94E+00	1.63E+01	1.47E+00
PCB138	3.09E+02	4.31E+00	8.02E+01	8.19E+00	3.58E+01	4.01E+00
PCB158	4.89E+01	1.45E+00	1.22E+01	1.24E+00	5.27E+00	5.81E-01
PCB178	5.50E+01	2.43E+00	1.76E+01	1.13E+00	9.90E+00	7.04E-01
PCB187+182	1.38E+02	4.51E+00	4.70E+01	2.66E+00	2.80E+01	2.29E+00
PCB183	8.29E+01	2.51E+00	2.93E+01	1.43E+00	1.68E+01	6.96E-01
PCB128	2.37E+01	1.58E-01	5.47E+00	5.57E-01	2.06E+00	2.08E-01
PCB185	1.28E+01	2.91E-02	4.38E+00	3.27E-01	2.51E+00	3.53E-01
PCB174	1.32E+02	4.64E+00	4.70E+01	3.33E+00	2.52E+01	2.18E+00
PCB177	9.16E+01	3.03E+00	3.27E+01	1.76E+00	1.76E+01	6.63E-01
PCB202	5.51E+00	4.84E-01	2.85E+00	1.41E-03	2.06E+00	1.56E-01
PCB171	2.55E+01	1.27E+00	9.40E+00	4.08E-01	5.28E+00	3.16E-01
PCB156	1.24E+01	2.90E-01	3.34E+00	2.90E-01	1.42E+00	1.23E-01
PCB157+200	5.53E+00	3.84E-01	2.77E+00	5.24E-02	1.97E+00	7.42E-02
PCB172	2.63E+01	1.05E+00	7.35E+00	2.81E-01	4.00E+00	1.28E+00
PCB197	1.79E+00	1.74E-01	8.72E-01	5.37E-03	6.24E-01	9.21E-02
PCB180	2.52E+02	7.09E+00	9.06E+01	4.96E+00	5.07E+01	3.67E+00
PCB191	7.96E+00	3.63E-01	2.94E+00	1.56E-01	1.50E+00	2.10E-02
PCB199	5.04E+00	2.78E-01	2.72E+00	2.02E-03	1.93E+00	1.99E-01
PCB170+190	1.12E+02	3.92E+00	4.03E+01	2.51E+00	2.12E+01	1.36E+00
PCB198	1.85E+00	1.83E-02	8.10E-01	2.24E-02	5.11E-01	2.57E-03
PCB201	5.23E+01	2.98E+00	2.56E+01	3.18E-01	1.75E+01	1.17E+00
PCB203+196	6.25E+01	2.83E+00	3.13E+01	2.60E-01	2.12E+01	1.38E+00
PCB189	3.77E+00	2.82E-01	1.36E+00	1.06E-01	7.21E-01	1.81E-02
PCB208	5.96E-01	ND	3.94E-01	1.97E-03	3.17E-01	6.77E-03
PCB195	1.19E+01	8.27E-02	6.09E+00	3.38E-01	3.92E+00	2.81E-01
PCB207	6.41E-01	ND	4.43E-01	1.37E-02	3.30E-01	ND
PCB194	2.87E+01	6.86E-01	1.44E+01	6.57E-01	9.26E+00	6.94E-01
PCB205	3.13E+00	5.76E-01	1.21E+00	1.06E-01	7.54E-01	9.55E-02
PCB206	6.60E+00	4.96E-01	3.68E+00	7.32E-02	2.58E+00	1.16E-01
PCB209	7.06E-01	6.38E-02	4.89E-01	1.43E-02	4.24E-01	1.58E-02
Total PCBs	**3.76E+03**	**2.05E+02**	**9.31E+02**	**7.79E+01**	**4.78E+02**	**2.68E+01**

Sample name	2×2 min mixing, 75-150 µm AC Average (n=2)	Deviation	2 min mixing, <45 µm AC Average (n=2)	Deviation	layered AC Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)						
PCB1	ND	ND	ND	ND	ND	ND
PCB3	ND	ND	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND	ND	ND
PCB6	ND	ND	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND	ND	ND
PCB18	ND	ND	ND	ND	ND	ND
PCB15+17	ND	ND	ND	ND	2.46E+00	ND
PCB24	ND	ND	ND	ND	ND	ND
PCB27	ND	ND	ND	ND	7.67E+00	1.19E-01
PCB16	ND	ND	ND	ND	ND	ND
PCB32	ND	ND	ND	ND	2.19E+00	ND
PCB26	ND	ND	ND	ND	ND	ND
PCB25	ND	ND	ND	ND	3.57E+00	ND
PCB31+28	ND	ND	ND	ND	3.31E+00	ND
PCB21+33+53	ND	ND	ND	ND	1.33E+01	1.58E+00
PCB51	ND	ND	ND	ND	1.13E+01	4.11E-01
PCB22	ND	ND	ND	ND	2.85E+00	ND
PCB45	ND	ND	ND	ND	6.54E-01	ND
PCB46	ND	ND	ND	ND	6.43E-01	ND
PCB52+49	ND	ND	ND	ND	4.84E+01	7.25E-01
PCB43	ND	ND	ND	ND	2.17E+01	1.15E+00
PCB47+48	ND	ND	ND	ND	ND	ND
PCB44	ND	ND	ND	ND	1.14E+01	ND
PCB37	ND	ND	ND	ND	ND	ND
PCB42	ND	ND	ND	ND	2.79E+00	ND
PCB41	ND	ND	ND	ND	4.14E+00	4.75E-01
PCB71	ND	ND	ND	ND	ND	ND
PCB64	ND	ND	ND	ND	ND	ND
PCB40	ND	ND	ND	ND	ND	ND
PCB100	ND	ND	ND	ND	ND	ND
PCB63	ND	ND	ND	ND	ND	ND
PCB74	ND	ND	ND	ND	ND	ND
PCB70+76	ND	ND	ND	ND	ND	ND
PCB66+95	ND	ND	ND	ND	ND	ND
PCB91	ND	ND	ND	ND	1.50E+01	4.11E-01
PCB56	ND	ND	ND	ND	ND	ND
PCB60	ND	ND	ND	ND	ND	ND
PCB92+84	1.25E+00	ND	ND	ND	5.69E+01	3.70E+00
PCB89	ND	ND	ND	ND	4.15E+00	6.92E-01
PCB101	1.20E+01	1.71E+00	3.18E+00	5.24E-01	2.62E+02	4.40E+00
PCB99	2.95E+00	2.13E-01	1.13E+00	1.12E-01	5.68E+01	1.97E+00
PCB119	4.77E-01	3.98E-02	ND	ND	5.71E+00	3.57E-01
PCB83	ND		ND	ND	3.99E+00	2.14E-01
PCB97	4.81E-01	3.62E-02	ND	ND	1.59E+01	1.23E+00
PCB81	4.10E+00	2.31E-01	4.66E+00	7.14E-01	6.69E+00	8.54E-01
PCB87	1.14E+00	3.35E-01	ND	ND	4.16E+01	2.76E+00
PCB85	1.79E+00	1.95E-01	ND	ND	4.46E+01	2.88E-02
PCB136	9.41E+00	1.40E+00	2.39E+00	5.56E-01	1.08E+02	1.99E+00
PCB110	6.38E+00	7.98E-01	2.00E+00	3.04E-01	1.43E+02	1.79E+00
PCB77	ND	ND	ND	ND	4.48E-01	ND
PCB82	ND	ND	ND	ND	ND	ND

PCB151	2.02E+01	1.67E+00	8.54E+00	1.06E+00	1.62E+02	5.41E+00
PCB135	1.15E+01	1.01E+00	4.21E+00	5.04E-01	8.44E+01	1.68E-01
PCB144+124+147	6.53E+00	5.87E-01	3.00E+00	9.78E-02	4.58E+01	1.54E+00
PCB107	ND	ND	ND	ND	4.36E+00	
PCB123+149	4.49E+01	3.52E+00	1.91E+01	2.22E+00	3.41E+02	1.04E+01
PCB118	2.61E+00	2.44E-01	7.97E-01	ND	5.47E+01	3.84E-01
PCB134	2.36E+00	1.26E-01	8.97E-01	1.05E-02	1.73E+01	2.23E-02
PCB114+131	ND	ND	ND	ND	ND	ND
PCB146	1.45E+01	8.53E-01	7.44E+00	5.12E-01	7.63E+01	4.15E-01
PCB153	6.88E+01	4.05E+00	3.78E+01	2.64E+00	3.69E+02	4.81E+00
PCB105	2.36E+00	2.87E-01	6.65E-01	5.16E-02	2.11E+01	1.65E+00
PCB132	ND	ND	ND	ND	1.08E+01	3.59E-01
PCB141	1.69E+01	9.94E-01	1.14E+01	1.10E+00	1.30E+02	6.02E+01
PCB137+176+130	6.74E+00	3.45E-01	3.56E+00	2.58E-02	1.47E+01	2.91E-01
PCB163	2.69E+01	1.62E+00	1.27E+01	9.79E-01	1.60E+02	3.55E+00
PCB138	5.68E+01	3.18E+00	2.96E+01	2.87E+00	3.35E+02	6.59E+00
PCB158	8.91E+00	5.51E-01	4.64E+00	4.84E-01	5.03E+01	7.72E-01
PCB178	1.48E+01	5.96E-01	9.94E+00	6.10E-02	5.27E+01	4.57E+00
PCB187+182	4.13E+01	1.27E+00	2.98E+01	7.29E-02	1.34E+02	1.01E+01
PCB183	2.68E+01	7.32E-01	1.88E+01	3.57E-01	7.99E+01	6.72E+00
PCB128	3.41E+00	1.79E-01	1.37E+00	1.50E-01	2.48E+01	1.99E-01
PCB185	4.40E+00	6.67E-02	2.94E+00	9.89E-02	1.29E+01	1.15E+00
PCB174	3.95E+01	1.40E+00	2.62E+01	4.67E-01	1.30E+02	1.12E+01
PCB177	2.90E+01	9.22E-01	1.83E+01	3.10E-01	8.24E+01	2.75E+00
PCB202	3.27E+00	3.55E-02	2.19E+00	1.02E-01	5.20E+00	5.27E-01
PCB171	8.54E+00	2.80E-01	5.57E+00	1.99E-01	2.29E+01	1.50E+00
PCB156	2.39E+00	1.31E-01	1.57E+00	1.60E-01	1.29E+01	4.45E-01
PCB157+200	3.72E+00	3.75E-01	2.17E+00	7.78E-02	4.84E+00	4.19E-01
PCB172	7.25E+00	1.48E+00	5.71E+00	3.00E-01	2.70E+01	1.71E+00
PCB197	9.99E-01	ND	6.25E-01	7.94E-02	1.68E+00	9.77E-03
PCB180	8.44E+01	2.47E+00	6.17E+01	1.27E+00	2.40E+02	2.18E+01
PCB191	2.71E+00	8.93E-02	1.87E+00	1.92E-02	7.17E+00	9.16E-01
PCB199	3.10E+00	4.33E-02	2.08E+00	7.93E-02	5.36E+00	2.65E-01
PCB170+190	3.61E+01	1.14E+00	2.57E+01	1.97E-01	9.90E+01	5.90E+00
PCB198	9.12E-01	1.48E-02	6.22E-01	6.18E-03	1.96E+00	ND
PCB201	3.02E+01	2.12E-01	2.03E+01	1.01E+00	4.94E+01	3.75E+00
PCB203+196	3.64E+01	2.56E-01	2.59E+01	1.40E+00	5.89E+01	4.23E+00
PCB189	1.37E+00	4.12E-02	1.09E+00	3.03E-02	3.31E+00	3.63E-01
PCB208	5.54E-01	1.07E-02	3.56E-01	2.83E-02	4.90E-01	ND
PCB195	6.89E+00	7.12E-02	4.91E+00	2.57E-01	1.11E+01	9.58E-01
PCB207	6.14E-01	2.73E-02	ND	ND	6.54E-01	ND
PCB194	1.67E+01	1.05E-01	1.22E+01	7.28E-01	2.64E+01	2.24E+00
PCB205	1.30E+00	4.13E-02	9.15E-01	2.12E-02	3.10E+00	ND
PCB206	4.54E+00	2.80E-02	2.80E+00	1.52E-01	5.80E+00	5.23E-01
PCB209	7.24E-01	3.84E-02	3.92E-01	8.94E-03	7.19E-01	ND
Total PCBs	**7.41E+02**	**3.52E+01**	**4.43E+02**	**8.69E+00**	**3.86E+03**	**9.24E+01**

Test Title	Sediment column studies			
Sample Sets	Flow, 24 month contact			
Sample name	control		2 min mixing, 75-150 μm	
	Average (n=2)	Deviation	Average (n=2)	Deviation
PCB uptake in PE (ng PCB/g PE)				
PCB1	ND	ND	ND	ND
PCB3	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND
PCB6	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND
PCB18	ND	ND	ND	ND
PCB15+17	4.96E+00	1.21E-01	ND	ND
PCB24	ND	ND	ND	ND
PCB27	ND	ND	ND	ND
PCB16	ND	ND	ND	ND
PCB32	1.46E+00	2.44E-02	ND	ND
PCB26	4.63E+00	7.74E-02	ND	ND
PCB25	ND	ND	ND	ND
PCB31+28	ND	ND	ND	ND
PCB21+33+53	1.46E+01	3.71E-01	ND	ND
PCB51	1.27E+01	2.88E-01	ND	ND
PCB22	ND	ND	ND	ND
PCB45	5.51E-01	7.75E-02	ND	ND
PCB46	4.98E-01	ND	ND	ND
PCB52+49	4.94E+01	4.89E+00	ND	ND
PCB43	2.24E+01	7.62E-01	ND	ND
PCB47+48	ND	ND	ND	ND
PCB44	1.17E+01	4.64E-01	ND	ND
PCB37	1.55E+00	3.36E-01	ND	ND
PCB42	2.70E+00	6.39E-02	ND	ND
PCB41	5.09E+00	6.51E-02	ND	ND
PCB71	1.74E+00	8.59E-02	ND	ND
PCB64	3.49E+00	8.73E-02	ND	ND
PCB40	ND	ND	ND	ND
PCB100	6.63E-01	ND	ND	ND
PCB63	8.16E-01	6.13E-02	ND	ND
PCB74	5.29E+00	2.57E-01	3.66E+00	1.88E+00
PCB70+76	9.27E+00	5.20E-01	ND	ND
PCB66+95	ND	ND	ND	ND
PCB91	1.60E+01	1.57E-01	ND	ND
PCB56	3.73E+00	4.35E-01	ND	ND
PCB60	4.10E+01	2.96E+00	ND	ND
PCB92+84	5.80E+01	2.99E+00	8.68E-01	ND
PCB89	5.21E+00	1.84E-01	ND	ND
PCB101	3.44E+02	3.67E+01	7.73E+00	ND
PCB99	6.61E+01	1.89E-01	2.27E+00	ND
PCB119	6.05E+00	1.41E-01	3.62E-01	ND
PCB83	4.57E+00	1.35E-01	ND	ND
PCB97	1.81E+01	9.47E-01	4.79E-01	ND
PCB81	6.51E+00	1.14E-01	2.24E+00	6.75E-01
PCB87	5.20E+01	6.27E+00	9.42E-01	ND
PCB85	5.60E+01	1.24E+00	1.50E+00	ND
PCB136	1.41E+02	1.58E+01	3.46E+00	2.51E+00
PCB110	1.88E+02	2.10E+01	4.47E+00	ND

PCB77	9.76E-01	ND	ND	ND
PCB82	3.35E+00	6.40E-02	ND	ND
PCB151	2.54E+02	2.73E+01	8.16E+00	4.57E+00
PCB135	1.16E+02	1.04E+01	4.72E+00	2.60E+00
PCB144+124+147	7.13E+01	7.18E+00	2.82E+00	1.51E+00
PCB107	4.86E+00	2.55E-01	1.17E+00	ND
PCB123+149	5.48E+02	5.81E+01	2.00E+01	1.09E+01
PCB118	8.03E+01	5.65E+00	1.92E+00	ND
PCB134	2.32E+01	2.43E+00	1.43E+00	ND
PCB114+131	1.81E+01	1.03E+00	1.71E+00	2.13E-01
PCB146	1.10E+02	6.57E+00	8.22E+00	3.78E+00
PCB153	6.27E+02	3.35E+01	3.82E+01	1.77E+01
PCB105	3.19E+01	9.43E+00	1.28E+00	7.56E-01
PCB132	1.36E+01	3.80E-01	2.87E-01	ND
PCB141	9.75E+01	9.36E+00	1.42E+01	2.92E+00
PCB137+176+130	2.34E+01	2.21E+00	4.70E+00	1.57E+00
PCB163	2.66E+02	2.64E+01	1.40E+01	6.92E+00
PCB138	5.71E+02	5.84E+01	3.11E+01	1.59E+01
PCB158	8.72E+01	1.10E+01	5.26E+00	2.47E+00
PCB178	8.92E+01	6.33E+00	1.20E+01	2.92E+00
PCB187+182	2.36E+02	1.28E+01	3.73E+01	8.65E+00
PCB183	1.44E+02	8.14E+00	2.40E+01	5.96E+00
PCB128	3.63E+01	3.09E+00	1.70E+00	1.13E+00
PCB185	2.39E+01	1.81E+00	3.48E+00	7.43E-01
PCB174	2.39E+02	1.76E+01	3.34E+01	8.98E+00
PCB177	1.54E+02	9.43E+00	2.39E+01	6.35E+00
PCB202	8.76E+00	2.67E-01	3.04E+00	2.36E-01
PCB171	4.24E+01	2.35E+00	6.96E+00	1.87E+00
PCB156	2.18E+01	1.95E+00	1.44E+00	8.34E-01
PCB157+200	8.83E+00	3.30E-01	3.37E+00	2.18E-01
PCB172	5.45E+01	2.54E+00	9.48E+00	1.41E+00
PCB197	2.91E+00	9.31E-02	1.19E+00	3.82E-02
PCB180	4.73E+02	2.70E+01	8.37E+01	1.97E+01
PCB191	1.38E+01	5.49E-01	2.51E+00	8.38E-01
PCB199	8.67E+00	4.89E-01	2.85E+00	2.80E-01
PCB170+190	2.05E+02	1.36E+01	3.38E+01	9.50E+00
PCB198	3.47E+00	2.49E-01	9.04E-01	1.41E-01
PCB201	9.25E+01	3.29E+00	2.86E+01	2.34E+00
PCB203+196	1.13E+02	3.56E+00	3.66E+01	3.84E+00
PCB189	7.01E+00	4.01E-01	1.50E+00	2.92E-01
PCB208	8.32E-01	4.45E-02	5.59E-01	1.19E-02
PCB195	2.16E+01	6.97E-01	7.14E+00	7.32E-01
PCB207	8.75E-01	1.97E-02	5.34E-01	2.63E-02
PCB194	5.31E+01	1.12E+00	1.76E+01	2.22E+00
PCB205	4.26E+00	8.60E-02	1.41E+00	1.66E-01
PCB206	8.62E+00	1.33E-01	4.05E+00	3.63E-01
PCB209	8.38E-01	3.68E-02	6.58E-01	1.57E-02
Total PCBs	**6.18E+03**	**4.80E+02**	**5.59E+02**	**1.63E+02**

2. Evaluate possible adverse effects of sorbent-amendment on local invertebrates

Test Title	Sediment PAH determination					
Sample Sets	Sediment PAH determination					
Sample name	Holy Island		Blyth Harbor		Blackwater	
	Average (n=3)	Stdev	Average (n=3)	Stdev	Average (n=2)	Stdev
PCB concentration (ng PAH/g sediment)						
naphthalene	9.43E-01	1.12E-01	1.43E+01	4.47E+00	1.13E+01	7.59E-01
acenaphthylene	1.11E+00	1.78E-01	6.90E+00	1.13E+00	9.78E+00	3.53E-01
acenaphthene	1.13E+00	2.79E-01	1.38E+01	1.60E+00	6.82E+00	1.21E+00
fluorene	2.18E+00	5.01E-01	1.97E+01	2.12E+00	9.40E+00	1.79E+00
phenanthrene	2.76E+01	2.30E+00	1.55E+02	3.26E+01	7.82E+01	2.06E+01
anthracene	8.53E+00	1.03E+00	4.69E+01	1.11E+01	2.07E+01	4.67E+00
fluoranthene	6.52E+01	1.36E+01	2.62E+02	3.01E+01	2.21E+02	4.41E+01
pyrene	5.78E+01	1.12E+01	2.35E+02	3.57E+01	2.16E+02	4.31E+01
benz[a]anthracene	5.26E+01	1.31E+01	1.89E+02	4.22E+01	1.63E+02	3.39E+01
chrysene	4.38E+01	1.17E+01	1.78E+02	3.57E+01	1.51E+02	2.82E+01
benzo[b]fluoranthene	3.04E+01	9.69E+00	1.20E+02	2.00E+01	1.54E+02	2.65E+01
benzo[k]fluoranthene	2.66E+01	7.95E+00	1.08E+02	1.54E+01	1.38E+02	2.43E+01
benzo[e]pyrene	2.15E+01	6.50E+00	9.19E+01	1.65E+01	1.13E+02	1.84E+01
benzo[a]pyrene	3.07E+01	8.71E+00	1.15E+02	2.07E+01	1.48E+02	2.43E+01
perylene	6.73E+00	1.44E+00	3.27E+01	8.71E+00	5.24E+01	7.27E+00
indeno[1,2,3-cd]pyrene	2.69E+01	8.52E+00	8.32E+01	1.97E+01	1.92E+02	2.85E+01
dibenz[ah]anthracene	6.48E+00	1.82E+00	1.91E+01	4.73E+00	4.65E+01	4.45E+00
benzo[ghi]perylene	2.45E+01	7.27E+00	8.69E+01	1.79E+01	1.44E+02	2.05E+01
Total PAHs	4.35E+02	9.88E+01	1.78E+03	3.06E+02	1.88E+03	3.33E+02

Sample name	Hunters Point		Richmond	
Replicate number	Average (n=2)	Stdev	Average (n=3)	Stdev
PCB concentration (ng PAH/g sediment)				
naphthalene	9.27E+00	1.33E+00	2.50E+02	1.00E+01
acenaphthylene	5.38E+00	5.70E-01	NA	
acenaphthene	3.11E+00	6.77E-01	NA	
fluorene	4.28E+00	3.61E-01	5.40E+02	2.00E+01
phenanthrene	3.65E+01	3.44E+00	NA	
anthracene	1.19E+01	4.05E-01	NA	
fluoranthene	9.92E+01	5.17E+00	NA	
pyrene	1.30E+02	1.45E+01	1.28E+03	4.00E+01
benz[a]anthracene	9.80E+01	2.49E+01	1.92E+03	9.00E+01
chrysene	1.11E+02	3.08E+01	1.98E+03	9.00E+01
benzo[b]fluoranthene	1.26E+02	6.61E+01	2.17E+03	1.00E+02
benzo[k]fluoranthene	9.53E+01	3.15E+01	4.90E+02	3.00E+01
benzo[e]pyrene	9.14E+01	3.07E+01	NA	
benzo[a]pyrene	1.23E+02	4.61E+01	3.25E+03	8.00E+01
perylene	4.56E+01	1.47E+01	NA	
indeno[1,2,3-cd]pyrene	1.37E+02	6.55E+01	1.01E+03	4.00E+01
dibenz[ah]anthracene	3.18E+01	1.79E+01	9.20E+02	8.00E+01
benzo[ghi]perylene	1.30E+02	5.24E+01	3.52E+03	1.00E+02
Total PAHs	1.29E+03	4.04E+02	1.74E+04	1.00E+03

Test Title	Sediment PCB determination			
Sample Sets	Sediment PCB determination			
Sample name	Holy Island		Blyth Harbor	
	Average (n=3)	Stdev	Average (n=3)	Stdev
PCB concentration (ng PCB/g sediment)				
PCB1	ND	ND	ND	ND
PCB3	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND
PCB6	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND
PCB18	ND	ND	ND	ND
PCB15+17	ND	ND	ND	ND
PCB24	ND	ND	ND	ND
PCB27	ND	ND	ND	ND
PCB16	ND	ND	ND	ND
PCB32	ND	ND	1.18E-01	8.72E-02
PCB26	ND	ND	ND	ND
PCB25	ND	ND	8.40E-02	
PCB31+28	ND	ND	5.26E-01	7.07E-02
PCB21+33+53	ND	ND	ND	ND
PCB51	ND	ND	ND	ND
PCB22	ND	ND	2.12E-01	
PCB45	ND	ND	1.92E-01	
PCB46	ND	ND	1.77E-01	1.55E-01
PCB52+49	ND	ND	1.93E-01	6.43E-02
PCB43	ND	ND	5.27E-02	
PCB47+48	ND	ND	ND	ND
PCB44	ND	ND	1.41E-01	
PCB37	ND	ND	1.31E-01	
PCB42	ND	ND	4.22E-02	1.18E-03
PCB41	ND	ND	ND	ND
PCB71	ND	ND	7.58E-02	6.01E-02
PCB64	ND	ND	ND	ND
PCB40	ND	ND	ND	ND
PCB100	ND	ND	ND	ND
PCB63	ND	ND	ND	ND
PCB74	ND	ND	ND	ND
PCB70+76	ND	ND	ND	ND
PCB66+95	ND	ND	ND	ND
PCB91	ND	ND	ND	ND
PCB56	ND	ND	ND	ND
PCB60	ND	ND	ND	ND
PCB92+84	5.98E-02	4.95E-03	2.32E-01	4.18E-02
PCB89	ND	ND	ND	ND
PCB101	ND	ND	8.93E-02	3.31E-02
PCB99	ND	ND	1.57E-01	9.02E-02
PCB119	ND	ND	ND	ND
PCB83	ND	ND	ND	ND
PCB97	ND	ND	3.15E-02	1.26E-02
PCB81	5.83E-02	0.00E+00	5.18E-02	1.03E-02
PCB87	ND	ND	8.68E-02	1.17E-02
PCB85	1.13E-01	5.49E-03	2.58E-01	9.86E-03
PCB136	ND	ND	1.51E-01	2.90E-02
PCB110	ND	ND	2.48E-01	2.98E-02

PCB77	ND	ND	ND	ND
PCB82	ND	ND	ND	ND
PCB151	ND	ND	8.70E-02	4.52E-02
PCB135	ND	ND	9.55E-02	8.41E-02
PCB144+124+147	ND	ND	ND	ND
PCB107	ND	ND	ND	ND
PCB123+149	ND	ND	1.81E-01	2.37E-02
PCB118	ND	ND	1.19E-01	4.55E-02
PCB134	ND	ND	ND	ND
PCB114+131	ND	ND	2.96E-01	
PCB146	ND	ND	5.27E-02	4.36E-03
PCB153	ND	ND	2.24E-01	2.22E-02
PCB105	ND	ND	1.49E-02	1.98E-03
PCB132	ND	ND	4.49E-02	5.27E-03
PCB141	ND	ND	ND	ND
PCB137+176+130	ND	ND	ND	ND
PCB163	ND	ND	1.30E-01	6.51E-03
PCB138	4.34E-02	5.06E-03	3.39E-01	3.52E-02
PCB158	ND	ND	1.02E-01	1.01E-02
PCB178	ND	ND	4.57E-02	1.02E-02
PCB187+182	ND	ND	ND	ND
PCB183	ND	ND	4.83E-02	6.60E-03
PCB128	ND	ND	2.09E-02	5.19E-03
PCB185	ND	ND	ND	ND
PCB174	ND	ND	5.70E-02	9.43E-04
PCB177	ND	ND	4.66E-02	7.93E-03
PCB202	ND	ND	ND	ND
PCB171	ND	ND	1.60E-02	1.15E-03
PCB156	ND	ND	2.93E-02	1.06E-03
PCB157+200	ND	ND	ND	ND
PCB172	ND	ND	5.10E-02	
PCB197	ND	ND	ND	ND
PCB180	ND	ND	1.69E-01	2.23E-02
PCB191	ND	ND	ND	ND
PCB199	ND	ND	1.70E-02	1.12E-03
PCB170+190	ND	ND	8.91E-02	8.88E-03
PCB198	ND	ND	ND	ND
PCB201	ND	ND	ND	ND
PCB203+196	ND	ND	ND	ND
PCB189	ND	ND	ND	ND
PCB208	ND	ND	ND	ND
PCB195	ND	ND	ND	ND
PCB207	ND	ND	ND	ND
PCB194	ND	ND	3.85E-02	4.01E-03
PCB205	ND	ND	ND	ND
PCB206	ND	ND	ND	ND
PCB209	ND	ND	ND	ND
Total PCBs	**2.74E-01**	**1.55E-02**	**4.49E+00**	**3.54E-01**

Sample name	Blackwater		Richmond	
	Average (n=3)	Stdev	Average (n=2)	Stdev
PCB concentration (ng PCB/g sediment)				
PCB1	ND	ND	ND	ND
PCB3	ND	ND	ND	ND
PCB4+10	ND	ND	ND	ND
PCB7+9	ND	ND	ND	ND
PCB6	ND	ND	ND	ND
PCB8+5	ND	ND	ND	ND
PCB12+13	ND	ND	ND	ND
PCB18	ND	ND	ND	ND
PCB15+17	ND	ND	1.21E-01	ND
PCB24	5.23E-03		ND	ND
PCB27	ND	ND	ND	ND
PCB16	ND	ND	6.32E-01	1.01E-01
PCB32	ND	ND	3.82E-01	7.07E-03
PCB26	ND	ND	ND	ND
PCB25	ND	ND	ND	ND
PCB31+28	2.48E-01	1.37E-02	ND	ND
PCB21+33+53	1.37E-01	3.06E-03	1.13E-01	ND
PCB51	ND	ND	3.40E-01	0.00E+00
PCB22	9.57E-02	4.36E-02	ND	ND
PCB45	4.62E-02	5.19E-03	3.56E-01	5.80E-02
PCB46	ND	ND	ND	ND
PCB52+49	8.84E-01	8.00E-02	1.57E+00	7.31E-02
PCB43	2.32E-01	3.21E-02	5.52E-01	1.65E-02
PCB47+48	ND	ND	ND	ND
PCB44	4.71E-01	6.19E-02	4.63E-01	ND
PCB37	ND	ND	ND	ND
PCB42	8.97E-02	0.00E+00	5.17E-01	3.30E-02
PCB41	1.81E-02	5.34E-03	ND	ND
PCB71	ND	ND	1.69E-01	4.41E-02
PCB64	6.40E-02	1.01E-02	5.23E-02	2.64E-02
PCB40	4.66E-02	1.15E-02	ND	ND
PCB100	ND	ND	ND	ND
PCB63	1.42E-01	1.64E-02	1.34E-01	ND
PCB74	ND	ND	ND	ND
PCB70+76	2.62E-01	9.90E-03	2.95E-01	2.97E-02
PCB66+95	2.96E+00	5.45E-01	ND	ND
PCB91	3.88E-01	5.90E-02	1.32E+00	3.54E-02
PCB56	ND	ND	4.98E-01	2.76E-01
PCB60	2.34E-02		ND	ND
PCB92+84	2.21E+00	4.64E-01	2.60E+00	1.70E-01
PCB89	5.54E-02	3.87E-02	ND	ND
PCB101	2.19E+00	5.64E-01	1.81E+00	9.90E-02
PCB99	9.02E-01	1.41E-01	1.29E+00	4.34E-01
PCB119	2.94E-02	1.74E-03	6.17E-02	3.72E-02
PCB83	1.47E-01	3.19E-02	2.05E-01	8.49E-03
PCB97	5.67E-01	1.03E-01	5.18E-01	1.44E-01
PCB81	1.58E-01	0.00E+00	2.06E-01	6.20E-02
PCB87	1.43E+00	2.99E-01	1.87E+00	1.01E-01
PCB85	2.79E+00	1.20E-01	5.63E+00	5.44E-01
PCB136	5.90E-01	1.70E-01	ND	ND
PCB110	3.56E+00	6.77E-01	2.35E+00	8.72E-02
PCB77	5.43E-02	3.35E-02	ND	ND
PCB82	2.97E-01	6.20E-02	2.69E-01	7.78E-03

PCB151		4.34E-01	9.48E-02	3.02E-01	1.84E-02
PCB135		4.74E-01	1.44E-01	3.34E-01	2.67E-01
PCB144+124+147		1.85E-01	6.21E-02	1.94E-01	ND
PCB107		2.95E-01	8.85E-02	3.54E-01	3.25E-02
PCB123+149		1.78E+00	5.27E-01	1.23E+00	4.71E-03
PCB118		2.50E+00	5.14E-01	1.95E+00	2.59E-02
PCB134		2.77E-01	6.94E-02	8.27E-02	2.12E-02
PCB114+131		2.20E-01	1.58E-01	5.14E-01	4.85E-01
PCB146		5.40E-01	1.75E-01	3.38E-01	2.12E-02
PCB153		1.94E+00	5.49E-01	1.14E+00	1.04E-01
PCB105		2.73E-01	8.48E-02	1.14E-01	2.33E-02
PCB132		6.61E-01	1.53E-01	6.10E-01	9.43E-03
PCB141		8.00E-01	8.41E-02	8.57E-02	ND
PCB137+176+130	ND		ND	ND	ND
PCB163		1.18E+00	3.39E-01	6.73E-01	4.71E-02
PCB138		4.26E+00	1.24E+00	2.03E+00	8.49E-02
PCB158		7.46E-01	2.54E-01	4.11E-01	1.58E-01
PCB178		4.96E-01	1.97E-01	6.72E-01	4.22E-01
PCB187+182		3.09E-01	4.39E-02	4.08E-01	1.18E-02
PCB183		2.43E-01	7.31E-02	2.63E-01	5.14E-02
PCB128		7.42E-01	2.13E-01	3.53E-01	1.41E-02
PCB185		3.02E-02	1.01E-02	2.38E-02	7.94E-03
PCB174		3.85E-01	1.09E-01	2.41E-01	3.06E-03
PCB177		3.14E-01	6.89E-02	2.21E-01	1.70E-02
PCB202		8.24E-02	2.50E-02	4.67E-02	5.19E-03
PCB171		1.20E-01	1.88E-02	7.58E-02	5.42E-03
PCB156		5.33E-01	1.09E-01	2.34E-01	1.46E-02
PCB157+200		1.94E-02		ND	ND
PCB172		1.69E-01	4.95E-02	1.83E-01	3.79E-02
PCB197		2.54E-02		3.08E-02	1.39E-02
PCB180		9.55E-01	3.28E-01	6.38E-01	2.59E-02
PCB191		4.73E-02	2.26E-02	1.84E-01	3.30E-02
PCB199		1.51E-01	1.17E-02	1.44E-01	6.67E-02
PCB170+190		6.52E-01	2.47E-01	3.07E-01	ND
PCB198	ND		ND	ND	ND
PCB201		3.34E-01	1.52E-01	2.64E-01	1.65E-03
PCB203+196		3.35E-01	1.33E-01	2.60E-01	6.60E-03
PCB189		4.88E-02	1.99E-02	ND	ND
PCB208		3.73E-02	1.79E-02	6.15E-02	4.95E-03
PCB195		3.88E-02	1.42E-02	ND	ND
PCB207		3.58E-02	2.34E-02	6.30E-02	ND
PCB194		1.96E-01	5.64E-02	1.28E-01	2.83E-03
PCB205		8.06E-02	7.26E-03	1.26E-01	2.14E-02
PCB206		1.71E-01	1.24E-01	2.03E-01	7.59E-02
PCB209		6.90E-02	1.17E-02	2.39E-01	1.70E-02
Total PCBs		**4.34E+01**	**9.37E+00**	**3.93E+01**	**1.65E+00**

Appendix E. PCB Mass Transfer Model Source File

The Matlab code and the Excel I/O files for the PCB mass transfer model developed in this study are submitted as separate files along with this report.

Appendix F. Responses to Comments on the Draft Final Report

The review comments for the draft of this Final Report have been received from the SERDP office on July 16th, 2013. The current version of the report is revised according to the review comments, and the responses to the review comments are presented in this section. The comments are shown in framed text boxes and the responses are written directly below each comment box.

1. **Table of Contents.** Please reformat the Table of Contents and the report text to include subsection headings. For example, in Section III (Background), it would appear that the five bolded sentences are subsections, and should be enumerated as such in the body of the report and in the TOC. Likewise in Section IV, "Site Description" should be assigned Section 1.1.1. This will aid the reader in being able to locate and cross reference sections from the TOC.

Response: Corrected. Subsection headings are included in the Table of Contents (pages ii-iv).

2. **List of Tables and List of Figures.** Please change the List of Tables and List of Figures so that only the pertinent, short sentence is reflected in the list. For example, Figure 1 should read only "Absorption efficiency results for various particle types for the marine clam *Macoma balthica*" in the List of Figures.

Response: Corrected. The first sentence(s) are shown in the List of Tables and List of Figures for conciseness (pages vi-viii).

3. **Section I: Abstract.** Please expand the Abstract to include more specificity on what was done and what was found. The current Abstract is very general and does not provide the reader with a clear sense of what was actually performed and accomplished.

Response: The Abstract is expanded to introduce the project objectives, approaches, and accomplishments more in detail (pages 1-3).

4. **Section I: Abstract.** The Abstract will be used to update the project web page. Please make the Abstract comprehensive by describing how the effort described in this report (Phase II) fits in with the entire project. Include a brief description of the objectives of the three phases of the project, as well as a brief summary of the results from Phase I with a link to that report, results from Phase II, and what is planned for Phase III.

Response: The overview of the entire project is provided and the relevance of the current phase (Phase II) to the other phases is described in the Abstract. The objectives of the three phases of the project are also summarized in the Abstract (page 1-3).

5. **General.** Please include tabular data with the revised report. All data generated as part of the report should be included as appendices to this report.

Response: All data generated for this project are now presented in Appendices C and D. The numerical data for figures presented in the report are provided in Appendix C and raw data report is presented in Appendix D.

6. **Model.** Please include the final model in the Excel/MathLab format.

Response: We already submitted the Excel and MatLab codes as separate files along with the draft Final Report. However, upon the submission of the revised final report, we submit the updated codes and spreadsheets again. Appendix E is created in the current report to guide readers.

7. **Section IV: Materials and Methods (1.1., Long-term field monitoring and initial development of the mass transfer of polychlorinated biphenyls in sediment following pilot-scale *in-situ* amendments with activated carbon).** Please provide additional specificity on the measures of TOC, sediment PCBs, and PCB congener analyses. For example, what method was used for the TOC analyses? For sediments and congener analyses, was an EPA method (e.g., 8082A) used? Please provide a reference and/or description for all analytical methods. All references should be complete, rather than referring the reader elsewhere.

Response: Detailed experimental methods and references are added in pages 11-13.

8. **Section IV: Materials and Methods (Table 2, Method detection limits for PCB congeners).** Please correct the spelling of "congener" in the Table title and change "ug/kg" to "µg/kg" in the table. For the Passive Sample Uptake, please clarify what is being measured (µg/kg PE, SPMD?). Additionally, please clarify why the sediment congener PCB MDLs were so high (an order of magnitude higher than is usually achieved using, for example, EPA 1668A). This may not impact the results, but it would also be useful to describe how non-detected data were used in the analysis.

Response: The typos are corrected accordingly (Table 2). Regarding method detection limits (MDLs), we did not have any signals below MDLs for both sediment and passive sampler samples. We only have some for aqueous samples from AC-treated plots, which were then set as MDL instead for the conservative AC benefits.

EPA 1668A reported estimated MDL for PCBs using high resolution GC. MDLs are certainly affected by instruments and sample preparation methods. For example, in the EPA 1668A, 20 µl of extracts for 10 g of sediment were analyzed, while our method used smaller sediment samples (~3 g) and larger volume of extract (1 mL) for analysis. Considering dilution factor, the discrepancy between our MDLs and EMDLs from EPA 1668A seems reasonable.

9. **Section IV: Materials and Methods (Model formulation).** Please provide a table that defines each of the variables listed in Equation 3. This table should also include all variables listed in Equations 3-6 (if different). Please also fix the last sentence on page 14, which is currently incomplete and incorrectly formatted.

Response: Table 8 is generated accordingly (page 23). The formatting issue is corrected (page 16).

10. **Section V: Results and Discussion (Long-term effectiveness of AC amendment).** Please provide tables showing the actual measurements/data used to construct Figures 17 and 18. To be clear, this should be the actual measures of PCBs (not percent reduction) for all replicates, as well as the mean/average calculated and standard deviation as expressed in the figures. It would also be helpful to include the corresponding model prediction(s) (as expressed in Figure 18A, for example).

Response: Data and simulation results for Figures 17 and 18 are provided in Tables C1 and C2 in Appendix C.

11. **Section V: Results and Discussion (Figure 18).** Additional clarification is needed to help understand these figures. For example, are the values expressed on the plots (e.g., 4.4, 3.2, 2.4) OC measurements? Evaluation of the figures is complicated by the x(presumed) AC measures, from 2.1 to 4.4, and the wide standard deviation bars in B-2 and B-3. Is there a way to normalize the data, for example, based on measured OC (divide the PCBs by the % OC)?

Response: The values in the plots are AC dose (the figure caption was revised for clarity). Although the dose normalization will certainly make the figures look better, normalizing the data by AC dose may be inappropriate for the two reasons. First, the TOC measurements and SPMD uptake sampling were not taken at the exact same locations, which may hamper a direct correlation between samplers and AC dose. To overcome this issue, for the 5-year data shown in Figure 17, sediment cores were collected right next to the passive samplers. Secondly, although a good relationship between AC benefit and AC dose were observed in our study, quantitative relationship or linearity has not been validated with varying contact times. Therefore, we believe the current figures deliver our data more objectively.

12. **Section V: Results and Discussion (Figures 24-30).** Please provide the data in an appendix in tabular format that supports each of these figures. This should be the actual measures of PCB congeners used to construct the ratios and reported percentages in these figures.

Response: Data for Figures 24-30 are provided in Tables C3-C9 in Appendix C. Both actual measurements and the reported ratios/percentages are shown in the tables.

13. **Section V: Results and Discussion (Application of the modeling results to engineering AC remedy).** It may not be accurate to state that a "cleanup goal expressed as sediment concentration is not applicable to AC treatment" (page 54). For practical reasons, in a feasibility study or a comparative of alternatives, a sediment-based cleanup number needs to be expressed (for example, as 1 ppm total PCBs). This is often necessary to define areas requiring remediation, and for removal actions, the clean-to number. Based on the way this model is constructed, could it not be used to calculate the freely-dissolved PCB concentrations with an AC-remedy? Would it also

not be possible to use this model to evaluate an MNR alternative, a no-action alternative, and a sand cap alternative (assuming that the model could accommodate additional "clean cells" above the contaminated PCB cells)? Please consider and provide any insights.

Response: The paragraph is modified accordingly (pages 56-57) and our insights for using our PCB mass transfer model for other remedy alternatives are described (pages 57-58).

14. **Section V: Results and Discussion (Figures 33-37).** Please provide the data in an appendix in tabular format that supports each of the figures in this section. These data should include the site name, the treatment, the number of worms input to the beakers and the number of worms recovered, the initial worm weight/individual, the final worm weight per individual, and any mean and/or standard deviation that may have been calculated. The need for data also pertains to the individual measures of N, protein, lipid, and glycogen.

Response: Data for Figures 33-37 are provided in Tables C10-C13 in Appendix C. The tables include all data listed in the comment.